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TRANSACTIONS

OF THE

AMERICAN INSTITUTE

OF

ELECTRICAL ENGINEERS.

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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

New York, November 20th, 1895.

The 101st meeting of the INSTITUTE was held this date, at 12 West 31st Street, and was called to order by President Duncan at 8:05 P. M.

Mr. W. J. Hammer, Secretary *pro tem.*, read the following names of associate members elected and transferred at the meeting of Council in the afternoon.

Name.	Address.	Endorsed by.
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GOTT, CLARENCE P.	Chief Engineer and Electrician Grand Central Palace. Residence, 83 Washington Place, New York City.	N. W. Perry. Wm. A. Rosenbaum. J. Elliott Smith.
HOPKINS, NEVIL MONROE	Scientific Literature. 1730 I Street, Washington, W. C.	Chas. A. Stone. H. M. Whitney. F. S. Pearson.

HUBBARD, ALBERT S.	Electrician, Alexander-Chamberlain Electric Co. Residence, 305 E. 34th St., New York City.	Harry Alexander. F. C. Bates. Townsend Wolcott.
MACCOUN, ELLICOTT	Ass't Supt. of the Electrical Dept. The Carnegie Steel Co., Munhall, Pa.	Wm. J. Hammer. H. S. Hering. Thos. Duncan.
PHISTERER, FRED'K WILLIAM	Graduate Student, Cornell University, residence, 84 Heustis St., Ithaca, N. Y,	Harris J. Ryan. E. L. Nichols. Fred'k Bedell.
RATHENAU, ERICH	Electrical Engineer, Allg. Electricitats Gesellschaft, Berlin, Germany.	W. D. Weaver. Cecil P. Poole. R. W. Pope.
WARREN, ALDRED K.	Proprietor, A. K. Warren & Co., 465 Greenwich St., N. Y., residence, New Brighton, S.I., N.Y.	R. T. Lozier. J. C. Bennett. W. G. Whitmore.
WEBB, HENRY STORRS	Instructor in Electrical Engineering. Lehigh University, South Bethlehem, Pa.	Alex. Macfarlane. W. H. Powell. J. H. Klinck.

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Approved by Board of Examiners, Oct. 11th, 1895.

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Total, 10.

THE PRESIDENT:—The subject this evening, gentlemen, is "Storage Battery Applications." It is remembered, of course, that this is a discussion, and the publication of remarks made is under the rules which govern the publication of discussions; that is, the matter is to be gone over by the Editing Committee.

Several gentlemen have been kind enough to send preliminary reports of what they are going to say, and I would call on Mr. A. E. Childs for the first statement to-night. In Mr. Childs' absence, I would ask Mr. Wolcott to read his communication.

Communications presented at the 201st Meeting of the American Institute of Electrical Engineers, New York and Chicago, November 20, 1895.

STORAGE BATTERY APPLICATIONS.

(A Topical Discussion.)

COMMUNICATION BY ARTHUR E. CHILDS ON "THE STORAGE BATTERY FOR CENTRAL STATIONS."

The object of this communication is to bring before the INSTITUTE the main facts and considerations concerning the application of accumulators in electric generating stations both for light and power. The fact that storage batteries have reached a point of high efficiency and low cost of maintenance, has stirred up engineers in this country to consider the application of storage batteries to their own plants, and thus the accumulator has assumed great importance at the present time, especially as power and light stations are so far developed that further increase in generating capacity means large additional expenditure, and in a great many cases the rebuilding of the entire plant.

Realizing, therefore, that storage batteries are eminently practical as auxiliaries, and that their utility and value are acknowledged throughout Europe, it is not surprising that engineers and managers in this country are inquiring about them with the end in view of securing the full measure of their advantages and benefits. In England and on the Continent, storage batteries have been used in central stations for more than five years, and the success of their application has brought about a great change of feeling regarding them; and the respect with which they are now regarded is an ample indication of the value they have been to managers in the operation of their stations.

It is an acknowledged fact that the great variations and fluctuations of the load on power circuits, especially those power circuits supplying trolley lines, are among the greatest difficulties which engineers have to contend against, and any appliances which will aid them to arrive at a satisfactory running of their station is looked upon with favor by them. It is only in the ranks of those short-sighted engineers, where ignorance and prejudice are the rule rather than the exception, that there are found

men who will refuse to consider the storage battery as an auxiliary.

In this paper the term "variation" is used to designate the change of current induced by the adding of lights on to a lighting station, or the cars or motors on to a power station. The term "fluctuation" is used to indicate those rapid and necessary changes of current taking place on the outside line, due to stopping or starting of cars or throwing on or off of stationary motors. Although they may be thus differentiated, they bear a certain relation to each other, and in applying a storage battery a study of the conditions will quickly indicate the type of battery which will be more favorable in each case. By the "type" of battery is meant the slow discharge battery for a long period of service, or the rapid discharge battery for a few hours, or even less time of discharge.

In the lighting station, if we bear in mind the usual form of curve, it will be remembered that the instantaneous changes of current are minute and almost imperceptible, compared with the steady increase or diminution of the total current of the station. Comparing the lighting curve with the usual form of power station curve, it will be noticed that the instantaneous changes of current are enormous compared with that in the lighting station curve. There is a similarity in the two curves in the fact that at certain hours of the day more cars are operated than at other hours, thus producing a general rise in the level of the power curve, corresponding to the throwing on of a number of lights in the lighting curve.

It is not the purpose of this paper to discuss the characteristics of the two curves, but to consider in a general way the application of storage batteries to the wiping out of the fluctuations and variations as they come upon the dynamos and engines. The introduction of a storage battery into a central station, acts in a certain sense as a buffer between the external load and the dynamos, taking the shock of the variations without throwing the same on the engines. In this regard they have the effect of reducing the average percentage variation in load on the dynamo, from a large amount to a very small one, making the operation of the machines more efficient. In fact, a storage battery acts as a regulator in this instance, maintaining as it does a constant voltage at the switchboard. This introduces the question of the efficiency of engines with varying loads; and, leaving out of account the reports by engine builders, who are naturally interested parties, it is a fact that not many extended and careful investigations of efficiency under varying loads have been carried out. Prof. W. C. Unwin, of the Central Institution, at South Kensington, has shown, however, that a decrease of mechanical efficiency has a serious effect on the economy of working with a variable load, and with a load varying from 100 per cent. to 25 per cent., the efficiency decreases from 85 per cent. to 40 per cent.

As applied to power stations, and especially where water power

is used, storage batteries are almost indispensable. The writer knows of several plants where the successful maintenance of a constant voltage on the machines is dependent upon the fact that an attendant sits by the governors of the wheels, and regulates them by hand, as the inertia of the water, even when the best water-wheel governor that has ever been produced is employed, is too great to allow the turbines to pick up or throw off the load with anything like the quickness with which it is thrown on or off by the outside circuit. The stations in mind are not small stations, as might be supposed at first thought, but are stations where several thousand horse power and over, are generated at certain hours of the day; and it is surprising that engineers of intelligence, who are usually quick to perceive the advantages of new applications, are still allowing their prejudices to prevent them from investigating the merits and value of accumulators as regulating governors in their stations.

In the application of storage batteries to the power station of a trolley system, it is not unusual to find the variation in load as much as 50 per cent. below the average horse power, and even as great as 200 per cent. above the mean load. These enormous fluctuations take place in the course of a few minutes, and are an expense to the railroad companies in at least three ways. In the first instance, they require the use of a dynamo capacity very much in excess of that required where the station is operated at a constant load. In the second instance, these fluctuations reduce the life of the machinery of the station, producing a very large depreciation account. In the third instance, the efficiency of the generating plant is very much reduced, as pointed out in a previous paragraph. It has been figured out in a number of instances that could the steam be utilized in a proper manner in the engines driving the dynamos, that at least 40 per cent. more work could be obtained from it.

When considering the application of storage batteries to illuminating plants, it is found that their value is equally as great as in the case of power stations, as the charging of the battery can be done while the plant is operating at light loads, thus making use of the power of their machines to great advantage. At the period of heavy load, the battery is able to take care of the peak of the load, and also to operate the lights during that period of the 24 hours when few lights are being supplied from the station.

The value of an accumulator plant attached to an illuminating station has been thoroughly demonstrated by the New York Edison Illuminating Company, and the Edison Illuminating Company of Boston, and recently in the plant of the Lawrence Gas Company, Lawrence, Mass. In the latter case the battery is used in connection with their Edison three-wire system, and is used in the regular way of carrying the peak of the load during the busy hours of lighting. The Lawrence Gas Company, after

operating this plant for a short period, have recently doubled their storage battery, as they have found it so convenient and useful that they believe their system would be much benefited by an increase.

The storage battery can also be used as a valuable adjunct to both power and lighting stations at points in their systems where it is difficult to maintain the voltage at periods of heavy load. In these cases the feeders are usually not sufficient to carry the whole current direct from the station. But during the periods of small load the feeders can be utilized up to their maximum allowable drop in potential, to charge battery sub-stations placed at these weak points. When the load at such points becomes greater than the capacity of the feeder, the battery comes into play, and carries the load in connection with the station supply at that point, thus maintaining the voltage and doing satisfactory and valuable service. There must be hundreds of street railroads in this country that have just such weak points, and it will only be in accordance with the established progressive character of American street railway and lighting engineers, to investigate the value to them of a storage battery, as soon as it has been brought thoroughly to their notice. This cannot but result in a widely extended use of the storage batteries for this purpose; and the expectations of those interested in storage batteries would not be exceeded if half the street railroads and direct current lighting plants in this country and Canada should adopt within the next few years storage batteries either at their central stations or at sub-stations, the more especially as they can now obtain storage batteries which are thoroughly reliable, and which can be installed under a guarantee.

The extent to which storage batteries have been used in England and on the Continent is very great; and it will surprise many engineers in this country to know that there are more than 20 lighting stations and several thousand isolated plants in Great Britain alone, using storage batteries. Further than this, there are in Germany 5,000 isolated plants and 15 railway power plants using storage batteries. In fact, 80 per cent. of all the central stations in Germany and Austria are equipped with storage batteries. In addition to the above, there are many stations in France, Italy, Holland, Belgium, Sweden, Norway, Denmark and Spain, and two or three in Switzerland.

A survey of the progress which storage batteries have made in European countries, indicates no very great change in the principles of construction, but the results seem to be rather due to a thorough analysis and appreciation of the requirements of each case. This has resulted in a proper use of batteries and a correct recognition of the limitations of their usefulness. This fact alone has contributed largely to their successful application. The great difficulty in this country has been that engineers have not recognized a proper limit to the usefulness of a battery, but have, in

many cases, far exceeded their specified limitations, and in this way have injured the batteries and cast discredit on them. It would be just as reasonable to overwork an engine until injured or worn out, and then declare that all engines were useless and expensive mechanical contrivances.

One point which has contributed largely towards the success of storage batteries in Europe, is the fact that engineers have endeavored to obtain long life and high efficiency even at the expense of increased first cost, and instead of attempting to obtain a large output per pound of element, they have limited themselves to a reasonable number of ampere-hours per pound. The result of this has been that the batteries in use in Europe have shown great endurance and solidity. The experience, however, which has been obtained with many American batteries has not been so promising as on the continent, owing to the lack of proper appreciation of them. It would be greatly to the advantage of American engineers if they would follow the lines laid down by their European confreres; and if, instead of waiting for some marvelous development in the manufacture of storage batteries, they should make use of the existing high class and efficient batteries which are now offered to the public, and by using them in a reasonable manner they would obtain valuable and even remarkable results.

Great progress has recently been made in manufacturing large batteries which have a capacity large enough to take care of the needs of central lighting and power stations, and engineers need no longer complain that they are unable to get the large cells which they require. In fact, manufacturers can produce cells having almost any given capacity.

Considering the efficiency of a storage battery, the factors which tend to reduce it are due to a loss in voltage, and in the quantity of current. These losses, however, are not so serious as they have been in the past, and manufacturers are at present able to guarantee a very high efficiency. In cells which were submitted to Prof. H. L. Callender, an ampere efficiency of 96.1 per cent was recorded, the watt efficiency being 84 per cent. In certain instances, however, known to the writer, these efficiencies have been slightly exceeded, and complaints from central station managers that they cannot obtain efficient cells are now groundless, as with the efficiencies named, an eminently satisfactory service can be obtained. It must be borne in mind that a loss of 16 per cent., or even 20 per cent, in the efficiency of the battery does not mean the loss of the same percentage in the output of the station, as the battery usually supplies, approximately, or even less, of the whole output in watt-hours, and it is, therefore, from that fraction of the whole output that the loss in the battery must be deducted.

In the matter of cost of maintenance of a storage battery outfit, it is now usual for the manufacturer to guarantee a fixed

annual percentage. This percentage varies from ten per cent in small plants to a smaller percentage in large plants, depending, of course, on the conditions of operation and the use to be made of the battery, a study of which will soon determine what percentage can be guaranteed. In first-class plants well installed and operated by careful engineers, the cost of maintenance can be reduced to the vicinity of 3.5 or 4 per cent. It is customary for the manufacturers to enter into a contract, in the case of large plants, guaranteeing that the cost of maintenance shall not exceed a certain percentage per annum for the period of contract. This can be carried out in two ways. Either the lighting or railroad company can pay the manufacturer the percentage specified, every year, and the manufacturer will inspect and keep the battery in first-class condition; or the company employing the batteries can inspect and order renewals themselves, in which case should the cost of maintenance exceed the percentage guaranteed, the manufacturer will not charge more than the specified amount. This is an exception rather than the rule, however, as the cost of maintenance is usually somewhat lower than that specified by the manufacturers, so that the company owning the battery is the gainer by the difference in percentage. By a thorough attention to details, both large and small, the percentage can be kept down to a very low figure; and it is to be regretted that the practice of engineers which prevails in Europe, of treating the battery with care and consideration, does not seem to exist among the engineers of this country, to the detriment of their own lighting or railroad plants, which would otherwise be able to utilize batteries in an efficient manner.

It must not be assumed from the above that storage batteries require an inordinate amount of care and trouble. On the contrary, they do not require either expense or great care. All that is demanded is regular and systematic attention on the part of those having them in charge. When such care is exercised, it is found that batteries perform a very valuable service, and largely reduce the operating expenses of the station—in many cases as much as 30 to 35 per cent. This reduction in operating expenses is, of course, due to the saving in cost of coal consumed, a saving which could not otherwise be obtained. Where water power is employed, a storage battery enables the water-wheels to be operated for 24 hours, storing current while the station output is reduced to a minimum, and aiding the station during the busy hours of the day. In many cases this practically doubles the output of the station without increasing the cost of installation to a corresponding amount. In fact, in many cases where water power is used, it would be impossible to double the power of a station, as there would not be enough water at hand to give double the power. This is especially true in those sections of the country where the power of small streams has been utilized and where the flow of water is continuous but not very great. In

addition to a storage battery acting as a receiver for storing the current while the station is not giving a large output, it also maintains, during the operation of the station, a perfectly uniform voltage, which would not be obtained with the varying load direct upon the water-wheels, on account of the difficulty in governing previously mentioned.

When an entirely new power plant is to be built, there is no doubt that by adopting the storage battery in the first instance, the initial cost of installation will be less than for the plant not using storage batteries, and the cost of operation of the station will certainly be very much reduced, when the station uses storage batteries. In the case of existing plants which have to be extended, it has been proved that a kilowatt-hour capacity can be added more cheaply to the station by the addition of storage batteries, than by the addition of generating machinery; while, of course, the cost of operation is much reduced.

Referring to the primary cost of storage batteries, the cost per kilowatt-hour output is relatively greater for small cells than for large ones, since the cost of manufacture is reduced per kilowatt-hour in the larger sizes, whereas the jars and tanks which are used to hold elements do not decrease very much with the decrease in size of the elements. The cost of shipment and erection are, of course, slightly less per kilowatt-hour with the larger sizes than with the smaller ones, and on the whole the cost per kilowatt-hour with the larger cells is less than with the smaller sizes. It is stated by the Electric Storage Battery Company that they are now installing large plants of the Tudor type at a cost per kilowatt-hour of about $37 to $40, which cost, it is understood, can be reduced in the larger stations. The question of cost, however, is one which must be studied out in each case where it is proposed to install storage batteries, and a consideration of the cost of installation of storage batteries with their attendant reduction in operating expenses, will very soon bring to the mind of purchasers that it is cheaper to invest in accumulators than to invest in additional boilers, engines and dynamos.

As previously stated, it has been the object of this communication to bring before the INSTITUTE the general facts and considerations relating to the installation of storage batteries as auxiliaries to power and lighting plants. Lengthy descriptions of plants already installed have been avoided, and those interested are referred to the published descriptions which are constantly appearing in the technical journals.

THE PRESIDENT:—Gentlemen, there is probably no one who has had more experience in storage battery work than Mr. Edgar, and I would like to call on him for the next contribution to this discussion.

COMMUNICATION BY C. L. EDGAR ON "PRACTICAL EXPERIENCE WITH STORAGE BATTERIES IN CENTRAL STATIONS."

To those interested in selling electricity, it is a source of great satisfaction that the storage battery discussion has, within the past few months, especially in America, taken on an entirely new phase. It has become a question of use, and not of manufacture.

For years we have all watched with great interest the various types of batteries put upon the market. We have discussed their value, at first confining ourselves as to whether they would work at all, and in later years broadening out the discussion as to how well they would work. We have watched the various companies interested in the manufacture of storage batteries fight one another in the courts, and we have wondered if it were ever to be possible to obtain a battery which did not infringe some one else's patent.

Until very recently it has not been possible to discuss from the standpoint of experience the economic merits of storage batteries, and it is particularly satisfactory to us to note that the discussion seems to have drifted away from the manufacturer to the user. To-night I am going to assume, at least for the purpose of this communication, that these perplexing questions have all been answered, and that we are finally on a par with our neighbors across the water, prepared to discuss the advantages of a commercial storage battery found ready to our hand.

Whatever may be the facts as to the existence of a commercial battery, some of us have purchased and are operating batteries which we consider satisfactory, and I will leave that part of the discussion to others, confining myself exclusively to their uses in an Edison system of circulation and distribution for lighting and power purposes, in thickly settled communities. As it appears to me, their uses can be classed under four great heads, as follows:

1st. To carry the peak of the load at maximum hours.
2nd. To carry the entire load at minimum hours.
3rd. To act as an equalizer or reservoir.
4th. For the equipment of annex stations.

There are many other special uses for batteries which can be naturally classed under one of these heads.

First, to carry the peak of the load.—In all systems of lighting, whether by gas or by electricity, there is a considerable portion of the connected load which is used only for two hours per day during the three or four months in winter. We have all of us, at various times, very earnestly discussed the probability of being able to widen out this peak as it is commonly known, and numerous schemes have been devised by which it has been made more or less of a hardship for customers to use their light at this time, special concessions being made at all other hours of the day or

night. It does not seem to me that any of these will avail. We cannot get around the fact that there are, in every large city, hundreds of stores which close up at six o'clock at night. The only need which they have for light is after it becomes dark. In this section of the country, darkness comes on about 4.30 in mid-winter, and these stores are bound to use their light from 4.30 to six o'clock, and have no need of it at any other time. These are facts which are entirely outside of the question of electric lighting, and nothing which we can do will change them.

It matters not whether the company has a large motor load in the daytime, or a large city contract at night. These are simply going to change the height of the curve at those hours. They are not going to alter the special shape of the curve due to the hour and-a-half of darkness during the business day.

This particular peak will be in some cases a much larger percentage of the total maximum output of the station than in others, but I think it is safe to assume that it is likely to vary only between one-third and one-half of the total. In the case of the company with which I am connected, we have found that if we divide our maximum load of the year into two parts, the upper half exists only for about two hours under ordinary circumstances, and four hours under exceptional circumstances for the five winter months.

Computing the kilowatts in these two halves, we find that the lower half contains 90 per cent. of the K. W. hours manufactured, whereas the upper half contains only about 10 per cent. This would prove the position taken by some engineers that if an extremely large station was to be constructed, it would probably pay to equip it with two types of apparatus—50 per cent. to be of the best economy and most expensive class known to the art. This to do the 90 per cent. of the work. The other 50 per cent. to consist of crude, cheap, uneconomic but reliable apparatus, to do the 10 per cent. of the work. The saving in interest on the lesser investment in the second class would be much greater than the extra cost of running this half, due to its poor economy.

In our particular case we find ourselves in precisely this position. Our company installed in years past about 4,000 H. P. of high speed, belted, bipolar apparatus, reliable but of poor economy. Some three years ago it changed to the other extreme and commenced to equip with the highest priced and most economical apparatus to be found in the market, and to-day there is about 4,000 H. P. of this apparatus in use.

The data which we have for 1894 and 1895 proves the statement which I have just made. Ninety per cent. of our kilowatts have been manufactured by the vertical, triple expansion, multipolar units, and yet the total capacity of this apparatus is not over 50 per cent. of our maximum output for the winter.

The application of the storage battery to these conditions is obvious. What we need and what all companies under generally

like circumstances need, is a piece of apparatus capable of doing two hours' work per day which is cheap, and which has fair economy. If storage batteries could be used under no other circumstances than these, it is, perhaps, somewhat doubtful whether it would pay to install them, but yet I am inclined to think that considering their first cost and the efficiency which we can obtain from them, it could be fairly proved that it would pay to use them rather than what I have designated as the cheap type of apparatus.

At the time our first battery was purchased, our standard unit was 650 H. P. We therefore called for a battery of 650 H. P. capacity for two hours. We eventually, under stress of circumstances, reduced this to one and a half hours and found that it cost considerably less than a first-class steam plant.

As all apparatus has to be installed for the express purpose of taking care of the maximum load, it seemed to us very clear that if we could save in our first investment by installing storage batteries which cost less than a steam plant, we were going to be able to do a given amount of work with a less amount of capital by this means than by any other. We thus decided to install a battery to take care of the peak, even if we obtained no other advantage from it.

Second, to carry the entire load at minimum hours—I think that the nature of the load curve in America is against the use of batteries for this purpose to anything like the same extent as abroad. With us there is only about six hours of minimum load, whereas, owing to the lack of motor business in Europe, the minimum there extends some days from midnight until three o'clock in the afternoon. Our minimum is so short that we are not able to save one shift of men nor are we able to save much in the fixed boiler room expenses from drawing the fires, banking the boilers, or any of the various other expedients used when the plant is not in operation.

Our generating department has gone through some exhaustive experiments, running first the engines for 24 hours a day, charging the battery at minimum load, and then turning around the next week and shutting down the steam plant for the six hours from midnight until six o'clock in the morning, and depending entirely upon the battery. The general conclusion seems to have been arrived at that the former is the cheaper method. Admitting this, the indirect advantages of the former, by which the battery is charged during the night, and can be used during the following day, are very much greater than if the battery were discharged during the night, as it could not be completely charged again until the middle of the afternoon of the following day.

I do not consider our conclusions final, as the local conditions might materially change the result. In our case it happens that the output at night plus the charging current of the battery, is

just equivalent to one of our standard units. If it were necessary to run two units to do this work, our conclusions might have been different, so that I think this is a case which has to be decided in each place on its own merits.

Third, to act as an equalizer or a reservoir.—It is this use of the battery with which we have been particularly pleased, and in order to understand, it is perhaps desirable to explain the needs which a modern station has for apparatus of this kind. Years ago a distribution company was equipped with one station, furnishing electricity through a system of feeders, supplied from one 'bus bar. All this is changed. To-day the modern station manufactures electricity in various places, transfers it from one station to the other at will, sends it out through a system of distribution at three or four pressures supplied from 'bus bars of varying potential. At the minimum hours of the day the electricity is manufactured by one set of dynamos, part of it being delivered to the 'bus bar in the station in which the dynamos are located, the remainder being sent out over tie lines to various annex stations and delivered there to the local 'bus bar. The amount of current is so small compared with the capacity of the various circuits that, practically the pressure delivered at the lamps is constant, notwithstanding the various roundabout ways in which it reaches them.

As the load begins to increase, the drop over the tie lines becomes noticeable, and it is necessary, by means of auxiliary dynamos known as boosters, to raise the potential of that part of the output which is delivered to the tie lines.

The load still increasing, it is necessary to start additional dynamos. These may be thrown in multiple directly with the original pair, and deliver the same potential as the others, or, if the condition of the load warrants it, they may be thrown in multiple with the original dynamos and the booster in series, and deliver the potential needed by the tie line. In this case the booster might be taken out of circuit.

The load on the tie line again increasing, the booster would be again put in use, and we would thus have the condition of a tie line supplied partly by a dynamo of the proper potential, and partly by additional current furnished by a booster, raising the potential from another 'bus bar supplying current locally.

This goes on until nearly the maximum load is reached. It then may be found, as it is sometimes in our case, that the original or main station is not equipped with sufficient dynamos to supply the local distribution. In this case the current over the tie line is reversed, and the annex station sends current to the original station, which arrives there at somewhat lower potential than is needed, and is there raised by means of a booster to the 'bus bar of that station. It is necessary to understand that these are every day occurrences, and if we were not equipped with a battery, it would be almost an hourly question as to what it was

necessary to do next, whether to start dynamos, stop them, change boosters or any other of the innumerable combinations which might be made. This trouble is intensified by the uncertainty as to what changes are going to take place in the output, and what the load is going to be at any given time. In a very large degree the battery answers all these questions or at least makes them unimportant. It makes it possible to determine beforehand what the regular day's work of the steam plant is to be, to decide how many and at what time boilers are to be put in service, when engines are to be started or stopped, and in general to operate the plant to its best economy, knowing that daily or hourly inequalities in the load, or uncertainties caused by the weather will be taken care of by the battery.

It is kept in multiple with one or the other or all 'buses at all times. It is supposed, for many hours of the day, to be standing idle with the ampere-meter at zero, but it may, without a moment's warning, be called upon to either give or take anywhere from one to 3,000 amperes on a side. It is possible in this way theoretically to keep every engine which is running, loaded up to its maximum economy at all times. Practically we have found it possible to never operate an engine with less than three-quarters load. The economy of the steam plant then more nearly approximates what is known as mill practice, which is the goal toward which we are all striving.

Having satisfied ourselves in the beginning that with a given amount of capital we could do more work with the battery than without it, we by actual practice came to the conclusion that we could by the same means do this same amount of work more cheaply. When we remember that we installed the battery for the express purpose of taking care of the maximum load, we are, of course, particularly pleased at the very great use we can make of it for this purpose of equalization, and yet, in addition to this, we have made enough tests to prove to our own satisfaction that we do not lose anything in fuel economy by this particular use of the battery. The watts lost by the inefficiency of the battery are made up more than fourfold by the better economy of the steam plant. We have taken typical winter days and figured out exactly the cost of running our system with the battery and without, and have proved that the actual coal consumed with the battery is a material amount less than without it. If, in addition to the fuel, we take into account the very great saving in the labor, the added reliability and the better service given, we will see that these uses of the battery are even greater than those for which it was originally installed.

I do not think it is possible to overestimate the advantages of storage batteries for the purpose of giving regularity and reliability to a system of distribution. With very sudden fluctuations in the load which are continually taking place, it is almost impossible with dynamos alone to regulate the 'bus pressure so

quickly that the pressure throughout the system remains constant. Of course, we have done this for years to the best of our ability, but it has necessitated keeping everything in first-class shape and having the employees of the company on the alert at all times to take care of this question. The uses of the battery very much simplify this problem. Very many times where in the past it was necessary to change the magnetism of the fields of dynamos, it is now necessary to do absolutely nothing, the battery acting as a reservoir, giving out quantities of current without any apparent change in pressure for the time being.

This question of regularity is very closely connected with the one of reliability. To those of us who are identified with central station work, there is a great sense of security when we realize that whatever may happen to the steam plant, we have sufficient battery to carry us over a few minutes of disorder. In our particular case, we have at the present time sufficient battery to run 60,000 lamps for five, ten or fifteen minutes, depending upon how great the emergency is. This advantage of the battery may not appeal to an outsider. I do not think they can realize the intense nervous strain to which all connected with the successful detail operation of the station are subjected. If a battery and a steam plant were on a par in all other respects than this, I should personally feel very much inclined to install it for this reason alone.

4. *For the equipment of annex stations.* This is a use to which we have looked forward with great interest, but up to the present time have had no occasion to make the use. There are in every city certain sections, located so far from the centers of distribution that it becomes a very serious and expensive matter to reach them with the regular three-wire system.

When we realize that it makes very little difference to which end of a tie line a storage battery is connected, we can see at once the special advantage which this type of apparatus gives us. If of such value that it will pay to install them, it is a matter more or less immaterial whether they are installed at the main station, or at an annex station connected to the main station by tie lines.

The fixed charges of running a battery room are very small as compared with those of a steam station, and there would not be any very material increase of fixed expense between one large battery located in a central point and half-a-dozen small ones distributed throughout the city.

Storage batteries, therefore, lend themselves particularly to the location of a "central" station at some convenient point upon the water front, and the building up of small centers of distribution scattered throughout the city, consisting of storage batteries with or without a steam adjunct, and connected together possibly, but certainly each one connected to the central station.

This communication may be considered to have been written upon very narrow lines and I may say that this was intentional.

So much has been written during the past few months upon generalities and upon possible cases which may or may not exist, that it is sometimes valuable to brush these all one side and to confine oneself to some specific cases. This I have tried to do.

Our company has used the first battery 20 months, and one of double its capacity for six months, entirely too short a time to come to any conclusions about the depreciation, but it has given us ample time to satisfy ourselves as to the economic value. It is sufficient for me to say that if a need should arise to-morrow for additional capacity, either at our main station, at either of the annexes or in any new part of the city, within reasonable distance of our center of distribution, we should consider the question along the lines which I have just indicated. We should eliminate entirely from the discussion, the question which has distracted the public mind for so many years and decide it entirely upon its merits, placing the battery side by side, and on an equality with other modern and improved apparatus.

THE PRESIDENT:—You have heard the exceedingly interesting and important contribution of Mr. Edgar. The next communication is from Mr. Nelson W. Perry.

COMMUNICATION BY NELSON W. PERRY, E.M., ON "THE STORAGE BATTERY OR THE GAS ENGINE AS AN AUXILIARY."

Whether it is economical or not to equip a central station with an auxiliary storage battery plant, is a question which must be decided separately for each particular installation. Generally speaking, the question will be decided by the character of the load line—a broad topped curve being the most unfavorable, and a sharp peak the most favorable to storage battery economy. Again, a station having a very light day load may use the battery to good advantage even though its night load may present a broad topped aspect.

Aside from purely economic reasons, convenience may be controlling, so that it is impossible to state unless all the conditions are known, whether the storage battery is advisable or not.

The price of the battery is an important element of course, but less so than popularly supposed, for the space which it occupies and the cost of maintenance may largely overbalance any gain in first cost over the cost of the extra boiler, engine and dynamo.

In regard to the cost of maintenance, manufacturers are willing to guarantee that it will not exceed 10 per cent. per annum, but it is well to understand just what this 10 per cent. means. It means, in the first place, that if you put in all the battery power that the manufacturer recommends, and take care of the battery exactly as he says, then the guarantee holds good. Under such

conditions the manufacturer is undoubtedly safe, but if we install a plant under these conditions we are pretty sure to find that the economy in first cost of the battery over engine and dynamo has entirely disappeared.

Then it is well to understand beforehand what the 10 per cent. means—10 per cent. of what?

Some time ago I had occasion to inform myself accurately on this subject and to this end entered into quite a correspondence with the president of the leading storage battery company of this country. As regards the guarantee, he wrote me under date of June 18, 1894, as follows:

"We send you by to-day's mail our illustrated catalogue and "would especially call your attention to the question of main- "tenance as contained on page 11. We undertake, in these cases, "to provide renewals when renewals are required, at a specific "price with a guarantee that this will not be required sufficiently "frequent (*sic*) to exceed an average of 10 per cent. per annum. "We have every reason to believe from our experience so far, "that the actual cost of maintenance when the batteries are used "at normal rates will not exceed five per cent."

Turning to page 11 to see what this meant, I found the following:

"This company is prepared to undertake maintenance con- "tracts according to a scheduled rate of charges, for periods up to "ten years or longer, under which they will guarantee that the "total amount paid for renewals during the term of the contract, "shall not exceed ten per cent. per annum on the *catalogue* price "of the cells specified in the contract. . . . . *In all cases of re-* "*newal by* contract the old material becomes the property of "the company, *and must be returned to their works free of* "*charge for carriage or packing.*"

[The italics are mine.]

Since the regular trade discount at that time was 20 per cent. of the catalogue price, and a further discount was offered which made the cost of the batteries comparable with that of an engine and dynamo, the guarantee assumed a very different aspect from that which it bore on its surface. When to this was added the cost of packing and carriage back to the factory, it ceased to be an attractive guarantee, and my calculations showed that in many cases where the storage battery might be recommended, if the guarantee was what it appeared to be, it would not be economical under the guarantee as it actually was.

As before indicated, there are some situations in which either convenience or extreme steadiness of current may be controlling in deciding the question of the use or not of storage batteries. But where the question is one purely of economy, I would not myself recommend their use under any circumstances, simply because there is a still more economical method at hand. I refer to the gas engine. Even if it were necessary to use illuminating

gas from the street mains it would be more economical (considering space and other factors), to take the peak of the load with a gas engine than to install a battery for this purpose. In this case there would be no standby losses and the engine would be ready at a moment's notice to be thrown into service.

It is a fact that has been amply demonstrated by others as well as myself, that a given number of lights can be produced with half the gas burned in a gas engine that is required to produce them in ordinary burners. The mechanical efficiency of the gas engine is not quite so high as that of large compound condensing steam engines, rarely ever exceeding 83 to 85 per cent., while the latter may go to 90 per cent., but the total efficiency from fuel to the pulley of the gas engine is about double that of the steam engine—reaching 25 per cent. under favorable conditions, whereas, with the steam engine it rarely equals 12 per cent. So that with the gas engine operating at anywhere near its full load, there would be a gain in efficiency, instead of a loss of say 20 per cent. where the battery was used.

As indicating the performance of a gas engine using illuminating gas at various loads, I quote the following figures obtained from a test of a 12 H. P. (actual) gas engine.

Actual H. P. developed.	Gas consumption (cu. ft.) each actual H. P.
12	15
11	15.3
10	15.5
9	16.
8	16.5
7	17.
6	18.
5	19.
4	21.
3	26.
2	30.
1	48.

These figures are somewhat better than would be obtained in practice, but go to show that the gas engine compares favorably at light loads with the steam engine under similar conditions.

Thus far I have spoken only of illuminating gas, but the power may be much more cheaply generated by using a fuel gas.

The cost of producers or generators comes to about $11.00 per H. P. capacity—considerably less than the cheapest boiler, and an idea of the space required may be gained from a statement of Mr. J. Emerson Dawson who in estimating for a plant of 400 K. W. capacity says that if the gas plant is all on one level it would occupy a ground space of 27 feet by 54 feet, but if necessary, all except the gas holder can be placed under or over the engine room. His estimate for such a plant is, including erection, foundations and ash pit for generators $5500 or $10.38 per H. P.

These fuel gas generators can utilize advantageously the poorest grades of fuel, and produce from the better grades of anthracite about 160,000 cubic feet of gas of a calorific value equal to one quarter that of 16 C. P. illuminating gas, per ton of coal.

As to the standby losses of the gas producers, this has been very carefully determined in a number of cases. As an illustration I will cite a single case—by no means the best on record.

At Openshaw a generator which supplied gas for from 250 to 300 I. H. P. was shut down for 41 hours, and the fuel consumption during this time was but 3.9 pounds per hour or about one per cent. When we compare this with the stand-by losses of the steam boiler which is estimated by Prof. Kennedy at ten per cent. of the total consumption in all the boilers, we see how insignificent it is.

A situation usually considered peculiarly adapted to the storage battery is in subordinate or outlying stations where they are charged during the day time from the central station, and act as centers of supply during the night time.

But gas can much more economically be distributed to these stations than can the electric current, for Mr. Denny Lane[1] has shown that with ordinary 16 C. P. gas, 3000 H. P. can be sent a mile for an expenditure of one H. P., or one-thirtieth of one per cent. of the power conveyed.

My own calculations show that a six-inch pipe will deliver 6,000 cubic feet of gas per hour at a distance of 10,500 feet under four inches of water pressure. If this be 16 C. P. gas, allowing 25 cubic feet per H. P. hour, this quantity represents 240 H. P.

Cast-iron pipe, six inches in diameter, having a thickness of $\frac{1}{2}$ inch, weighs 31.9 lbs. per foot. The total weight of this two miles (nearly) of pipe will therefore be 334,950 lbs. This would be equivalent in conductivity to about 41,869 lbs. of copper. But four miles of copper weighing 41,869 lbs. would be equivalent to about four No. 000 B. & S. wires, which would have a resistance for the four miles of 0.325 ohms. If the charging current were transmitted at 220 volts, there would be required a current of 848 amperes; but a wire having a resistance of .325 ohms will only deliver under a pressure of 220 volts $220 \div .325 = 677$ amperes, there would, therefore, be required five No. 000 B. & S. wires to deliver this energy, and the weight of this would be 53,540 lbs.

If the distribution took place at 1,000 volts, the amperes required would be approximately 180. To deliver this at the same distance with a loss of 10 per cent. would require 6,264 lbs. copper, and to deliver it at one per cent. loss would require 62,642 lbs. which would cost far more than the pipe, and still give less efficient transmission.

I think it would be very easy to prove that the gas engine with fuel gas, would prove a much more economical auxiliary to the central station for taking the peak of the load, and the loads amounting to fractions of a unit, than the storage battery, and

1. *Electrician*, Oct. 9, 1891.

when we consider the efficiency of transmission of energy in the form of gas, which will permit of the location of the gas generators where land is cheap and fuel easily procured, it seems to me that the plan must commend itself to electrical engineers.

Unfortunately the gas engine business in this country seems to be in the hands of parties totally incompetent to handle it properly, as every one knows who has ever had occasion to seek information from them.

It is probably not too much to say that every attempt thus far made in this country to adapt the gas engine to electric lighting has proved a failure. Our own manufacturers either do not know what their engines are capable of doing, or else they are afraid to make public what they will do. I believe there is not a single manufacturer who has a printed price list, and my own experience and that of others whom I know, has been that it is impossible to get prices quoted, until the manufacturer or his agent has been thoroughly satisfied of the exact purpose for which the quotations are desired. Information of any kind is almost impossible to get; and guarantees of performance, when given, are worthless. To such an extent is this true, that nearly all, if not all the recent large orders for gas engines have gone abroad where the business is conducted on business principles.

In England, Germany and France the gas engine has come into extensive use in isolated lighting, and already has been adopted with satisfactory results in several central stations of considerable size.

When the business is properly handled in this country, we may expect to see the gas engine make its way rapidly in the lighting industry here also, for it has merits which need only be known to be appreciated.

THE PRESIDENT:—The next communication is from Dr. Crocker. on the "Use of Storage Batteries in Electric Lighting."

DR. FRANCIS B. CROCKER:—In spite of the fact that my communication was printed in advance of Mr. Edgar's, I think that he has really anticipated me in the subject matter, and has gone much further than I even attempted to go. He has already given you the uses to which storage batteries may be put in central stations. I have considered the matter rather more generally, that is to say, I have attempted to give the various possible applications in electric lighting, but I did not try to cover any of them very completely.

COMMUNICATION BY DR. FRANCIS B. CROCKER ON THE "USE OF STORAGE BATTERIES IN ELECTRIC LIGHTING."

The function of accumulators is to receive electrical energy at one time or place, and to give it out at some other time or place.

The principal uses to which they may be put in electric lighting are the following:

1. To supply portable electric lamps.
2. To take up fluctuations and thus steady the voltage or current.
3. To furnish energy during certain hours of the day or night and enable the machinery to be stopped.
4. To aid the generating plant in carrying the heavier load which usually exists for only an hour or two.
5. To make the load on the engines more uniform by charging the battery when the load is light
6. To transform from a higher to a lower potential by charging the cells in series and discharging it in parallel, or *vice versa*.
7. To subdivide the voltage and enable a three or a five-wire system to be operated with a single dynamo.
8. To supply current from local centers or sub-stations.

Each of these applications will be considered separately in the above order.

1. *Portable accumulators.*—The accumulator is practically the only means of supplying portable electric lamps or those which are not connected to a dynamo even if they are stationary.

The primary battery is expensive and troublesome to operate, and it has never been commercially successful for electric lighting, except where only a few small lamps are required. Nor is there any other satisfactory primary source of electrical energy except the dynamo driven by mechanical power. It is therefore practically essential to adopt accumulators wherever portable electric lamps are used.

The serious drawback with portable accumulators is their great weight. For example, a standard size which weighs 100 pounds, yields ten volts and five amperes, or 50 watts for ten hours, which is just sufficient to feed one ordinary incandescent lamp of 16 candle power. This weight would be prohibitive in most cases in which the only way to carry the battery was by hand, but it might be allowable for lighting railroad trains, where the weight would not be so objectionable.

Their great weight would also discourage in most instances the use of accumulators for supplying lamps in places which are not connected to a generating plant, the batteries being carried back and forth from a charging station. This method might be resorted to on special occasions, such as a fete, to which ordinary commercial limitations do not apply, but for regular lighting it would be troublesome and expensive.

Small accumulators are used to feed miniature lamps for medical or dental purposes, in which case their weight is not a serious difficulty in view of the importance of the work and the small amount of energy required. Small batteries are also employed for theatrical lighting effects in which the lamps and batteries are carried by the performers when it it is not convenient to supply lamps by a wire connection.

2. *Accumulators for preventing fluctuations*, due to unsteadi-

ness in the driving power, are often applied successfully. A dynamo driven by a gas engine, for example, may vary periodically in speed because of the explosive action of the gas in the cylinder, and a battery connected in parallel with the dynamo will have the effect of steadying the voltage. But improvements in design and construction tend to reduce unsteadiness of speed, and by the use of a heavy fly-wheel, and an elastic connection between the engine and dynamo, the result is sufficiently satisfactory in most cases to make a battery unnecessary. An accumulator is generally installed in connection with a small gas engine lighting plant, to enable the engine to be stopped for a considerable portion of the time and thus save labor and attention, in which case the battery may also act to prevent fluctuations, but its principal function is the former one which will be considered next.

A windmill electric lighting plant absolutely requires an accumulator or some other means of storing energy not only to eliminate fluctuations in speed which are constantly occurring, but also to bridge over the considerable periods of calm weather.

3. *Accumulators to enable machinery to be stopped* during certain portions of the day or night. The advantage of this application depends upon the fact that in almost every electric lighting plant there are long periods during the day and late at night when the number of lamps lighted is so small that it may not pay to run the generating machinery.

This plan also allows the machines to rest and cool down which greatly facilitates cleaning and repair. In a hotel, residence, or on board of a yacht it may also be very desirable to stop the machinery and avoid the vibration and noise during the night. On the other hand, the addition of an accumulator to an electrical plant renders the latter heterogeneous, since the battery and its management differ so radically from the machinery and the handling of the same. It must also be remembered that the total investment is increased by the cost of the battery and its accommodation, because the generating plant is perfectly able to carry the load put upon the battery, since by hypothesis, this load is a light one. Hence the machinery might be run all the time, in which case the battery would be entirely unnecessary and sufficient rest for the machinery could be secured by using different machines for the periods of light load on successive days. These statements are based upon the supposition that the battery is not used to help the dynamos at the time of maximum load, since this case will now be considered separately.

4. *Accumulators to aid in carrying the maximum load.*—If accumulators are substituted for a certain portion of the dynamo capacity, the question arises whether the substitution secures any advantage. In regard to first cost, authorities differ widely. These discrepancies probably arise from the confusion between K. W. and K. W. hour of output. Most accumulators have a normal time of discharge of about 10 hours, hence the cost per K. W.

hour is only one-tenth of the cost per K. W. of output, and this would, of course, vary with any change in the time of discharge. In many cases it is specious and leads to mistakes, to speak of K. W. hours, to appreciate which fact we have only to realize that the K. W. hour capacity of a dynamo is almost infinite, since it might run for twenty years. The actual K. W. of output, or in short, how many lamps can be simultaneously fed, is the question in electric lighting. Moreover, in most cases, the time of discharge of an accumulator is unnecessarily long, and this is particularly true when it is used to help carry the heavy load which usually lasts only one or two hours. In this case the remaining hours of available discharge are of little or no use. If it be attempted to discharge more rapidly, both the capacity and efficiency are reduced, and in many types the condition and very life of the battery are injuriously affected by a high rate of discharge. What is needed for the maximum load or "peak of the load diagram" is an accumulator with a normal time of discharge of two or three hours and having a correspondingly smaller first cost, bulk and weight, that is, about one-quarter of those of the ordinary forms of battery, but certain types of cell are capable of discharging at this rate. It is evident that the time of charging need not be made as short as that of discharging, if it happens to be more convenient to charge less rapidly.

The use of accumulators to enable the machinery to be stopped, which is a case already discussed, usually demands a time of discharge of from 10 to 14 hours, which agrees quite well with the normal discharge rate of the ordinary forms of battery, but even then the time is unnecessarily long, since the average rate of discharge would rarely exceed one-half of the maximum rate. Consequently the battery would either be incompletely discharged, or the rate would have to be made excessive at certain times.

5. *Accumulators to maintain uniform load on the engines.*—Steam engines are very inefficient at light loads. This inefficiency, in fact, is one of the chief sources of loss in an electric lighting plant, and the principal object of the engineer who designs and operates a station should be to reduce this waste to a minimum. The accumulator is the most important means of accomplishing this result, although there are other methods such as gas, thermal (hot water) and steam storage, all of which have been carefully compared by Mr. Nelson W. Perry in a paper before the National Electric Light Association, February, 1895, "Storage of Energy Essential to Economy of Working Central Stations." Judicious selection of the number and sizes of the engines would enable them to be worked at a considerable fraction of their full capacity nearly all of the time, and it would seem that the same care that would be required to manage the battery might enable this to be accomplished. Nevertheless the accumulator gives more flexibility to the plant, and where introduced it often seems to considerably increase the

economy of the engines by making their load more uniform and nearer their full capacity. According to the figures given by Mr. Perry in the paper cited above, an electrical horse power costs $48.68 per annum when developed steadily, and costs $117.78 per annum with a variable load similar to that of an electric light station, that is, the latter costs about 2.4 times as much as the former. This ratio seems very high, but is borne out by statistics[1] which give a very large coal consumption for most electric light stations.

Under these circumstances almost any method of making the engine loads more uniform, should increase the economy of working. Doubtless an accumulator would benefit any plant in which an engine runs for any considerable portion of the time at less than half of its full power.

If a plant is so small that it contains only one engine, it may be necessary to run it a great deal of the time far below its full load. But even with two engines it is generally possible to select the sizes so that the smaller one runs economically during the periods of light load, the larger one alone is suited to medium loads, and both are used for the maximum output, the times during which any engine is very much underloaded being very short. With a greater number of units, it becomes still easier to properly apportion the load, and when there are five or more engines as is usually the case in large stations, the loss from this cause should be trifling. To be sure the waste of energy which occurs from using boilers for variable loads still remains, but according to the figures given by Mr. Perry this is less than that due to the engines, and general experience shows this to be true.

6. *Accumulators used as transformers.*—If the cells of a battery are arranged in series while being charged, and in parallel for discharging, a high voltage current will be required for charging and a low voltage current will be given out. The total amount of energy measured in watts is the same minus the loss of 15 or 20 per cent. which always occurs in accumulators. The result is similar to that obtained by an alternating current transformer or motor-dynamo. Such a method of transformation of potential might be employed in connection with long distance transmission of energy, the current being sent over the line at high voltage and converted to low voltage by accumulators for local distribution. For potentials of several thousand volts which are commonly employed in transmitting long distances, the number of cells required would be so great as to make this of doubtful practicability compared with the ordinary stationary or rotary transformers, but it would give uniformity in load and other advantages which may be secured by the storage of energy.

7. *Accumulators used for subdividing voltage.*—This application is similar in principle to the preceding. The most import-

1. See Report of Committee on Data to National Electric Light Association, *Electrical World*, March 2d, 1895, p. 273.

ant practical case is that in which a dynamo of 220 volts charges a battery of corresponding potential, a three-wire system being supplied from the battery, the neutral wire of which is connected to the middle point of the battery. This arrangement avoids the necessity of running two dynamos, and allows the battery to be placed in a sub-station near the districts to be supplied, so that it is only necessary to run two conductors to that point instead of three. The same principle may be applied to the five-wire system.

8. *Accumulator sub-stations.*—The plan of installing battery plants at local centers which are charged from the main station, enables some of the conductors to be saved in a three or five-wire system, as already stated. It also makes it possible to reduce the size of these conductors, because the current which flows over them can be kept practically constant, so that it is not necessary to have them large enough to carry the maximum current consumed by the lamps which may be several times the average value. This, of course, gives the same steady load on the generating machinery as if the battery were located near it

The batteries at the various sub-stations may be connected and charged in series or in parallel. The former plan is similar to case 6 and would require far less copper in the conductors, since the voltage is multiplied by the number of batteries in series, and the current is the same as for a single battery. On the other hand, this high difference of potential would exist between the first and the last batteries of the series, and if either of them became grounded, any person connected to the earth and touching a wire supplied by the other battery would receive a shock due to the total voltage. This would demand that the maximum difference of potential should not exceed 500 volts, or, in other words, four batteries of 110 to 125 volts each might be charged in series and could be connected to the lamp circuits at the same time. This would practically amount to a five-wire system using accumulators to subdivide the potential as explained in case 7. If the batteries were entirely disconnected from the lamp circuits while being charged, the latter would be free from danger of the high pressure which might therefore be 1,000 or 2,000 volts if desired, the batteries being charged during the day and supplying the lamps at night. For continuous working, two batteries would be necessary. Accumulator sub-stations not only save copper in the feeders but also reduce the cost of, and lost voltage in the distributing conductors because the batteries can be placed near the lamps to be supplied with current.

Accumulators used for two or more of the above named purposes.—Each of the different uses of the storage battery has been considered separately, to avoid the confusion with which this subject is often beset, but as a matter of fact the employment of the accumulator for several of these purposes is the most common

practice. By thus combining these different applications, the plant may be rendered not only more economical but also much more flexible. For example, the battery may be utilized to help out the generating machinery at times of heavy load or when the latter is partially or wholly disabled. It often happens that it is difficult to produce or maintain sufficient steam pressure owing to poor draught or other circumstances, in which event a battery enables the boilers to be temporarily relieved of some or all of the drain upon them while the pressure is being raised to the proper point. It may also be necessary or desirable to shut down the machinery or a portion of it for a few minutes to make some repair, adjustment or change of arrangement, connection, etc.

It is also possible to feed some of the circuits from the battery, while the others may be supplied at a higher or lower voltage by the machinery. In these and many other ways an accumulator may be a very convenient adjunct to an electric lighting system. The fact that it is so radically different from the machinery in its nature and action, makes it very unlikely that the entire plant will be crippled at any one time, since the two sources of current are not exposed to the same dangers. An accident to the steam piping, for instance, might shut down all of the machinery but it probably would not affect the battery, and *vice versa* an accident to the latter is not likely to extend to the former.

Communication by Carl Hering on "Past and Present Obstacles in the Storage Battery Development."

The great and numerous advantages of a satisfactory electric storage battery have been described so often, and are so well recognized and admitted by the unbiased, that it seems unnecessary to again enumerate and discuss them here. The question which the engineer and constructor should discuss at present is not "Is a battery desirable?" but rather "Why is it that storage batteries seem to have been unsatisfactory?" and the question which concerns the capitalist is "Does it pay in dollars and cents to use the storage battery even if it is kept in a satisfactory condition by the makers?"

The latter question can be disposed of here in a few words. If the makers guarantee to keep the battery in a satisfactory condition for a certain rate per annum, or if they rent them, then it becomes a mere matter of calculation to find whether it pays or not; but this calculation must be made for each specific case, as the cost of the batteries and their maintenance seem at present to be such, that an estimate for a general case can hardly be considered conclusive, the margin being in many cases too small. In some specific cases it will be found to be decidedly cheaper, in some it will be doubtful, and in some, decidedly too expensive. Limiting ourselves to this country and judging in a gen-

eral way from the number of storage battery installations, it would seem that the price at present (including of course the cost of maintenance) is such that in perhaps the majority of cases the margin of profit to the user is so small or so doubtful, that it does not balance the supposed risk. The commendable practice of renting, relieves the purchaser of this risk, which then leaves the question a mere matter of cost. A material reduction in the first cost and cost of maintenance, would therefore at once turn the tables in many cases so decidedly in favor of the storage battery, that there would be little doubt left as to the economy, and it would render the practice of renting unnecessary in most cases. Cheapness, therefore, is one of the most important points which affect the outlook of the storage battery.

To return to the first question "why is it that storage batteries seem to have been unsatisfactory" we must limit ourselves to this country, as probably thousands of tons are, and have been in successful use abroad. In Germany for instance, almost every one of the large continuous current central stations is equipped with a battery plant; in England they are used very largely for private plants, as also for central stations; an English firm recently claimed to have sold a total of "six miles" of accumulators placed in one continuous row, and a French firm is stated to make several tons a day.

The chief reason why so few storage battery plants exist in this country, seems to have been that the accumulator companies have for years been so busy fighting each other's patents and have spent so much money in this litigation, that they have had neither time or money left to manufacture and install their batteries. But all this litigation has now come to an end, thanks to an enterprising company which has bought up all the little life that is left of these historic "pasted plate" patents. This, together with the fact that it is now conceded by many authorities that for many if not most purposes the unpatented Planté type of cell is the better, removes the chief obstacle in the storage battery development in this country. The fact that the companies have been too busy with litigation to attend to legitimate business, has shaken the confidence of the public who naturally ask "where are your batteries in use," the only and unsatisfactory answer to which is "abroad." Much "missionary work" must first be done before public confidence will be restored, and let us hope that the recently started "rental" companies will soon accomplish this. It is up-hill work, but prospects at present seem bright and encouraging.

As the patent question has now been settled, and as cells of the Planté type have now been developed into practical forms, the storage battery outlook at present lies largely in the hands of the constructing engineer, and we should therefore look at the question from this standpoint.

The storage battery has for years had the reputation of being

like a delicate, sickly baby, continually threatened with half-a-dozen diseases, and requiring the constant attendance of a trained nurse, besides the fatherly care and large purse of its manufacturer. To the user the five chief diseases of the accumulators appear to be: buckling, short-circuiting, sulphating, disintegration and dropping out of the peroxide. Many inventors have thought that most of these may be made uninjurious by a process of opposing or resisting their disastrous effects, as distinguished from preventing their occurrence, although the term "preventing" has incorrectly been used to describe it. Buckling has been opposed by main strength and sometimes awkwardness; short-circuiting by porous insulating sheets between the plates; falling out, by enclosing or locking the peroxide so that it cannot drop out, etc. Whether and how far such heroic methods have been successful can be determined only by tests, but it seems to the writer that many of the methods are like curing corns by cutting off one's feet; the cures may be effective, but can hardly be called satisfactory. To attempt to prevent the almost irresistible force of expansion of the peroxide from exercising itself, by confining the material in an inelastic lead frame, is a formidable and it seems, an almost hopeless task; the inevitable result is that one or the other must give way; if it is the peroxide, it will ultimately be crumbled by the pressure; if it is the lead, there will probably be buckling or at least a separating of the contact surfaces at the subsequent contraction of the peroxide, and this inevitably results in the formation of that very objectionable layer of white sulphate which practically insulates the active material from its conductor, the consequences of which are sure to be fatal. The development of the storage battery has been greatly retarded by the fact that it was in the hands of mechanical engineers instead of chemists.

The careful constructor should attack the problem in a different way; he should go back to the beginning to find out the prime causes, and then prevent, if possible, these causes from arising, rather than to attempt to oppose their effect by sheer force and awkwardness. These causes seem now to be understood, and the question therefore is how to prevent them. One way is to supply with each battery a printed and neatly framed long list of "don'ts" or limitations in the form of rules telling you what you must not do, with a foot note attached, saying, that the company's guarantee ceases if these rules are violated. This may be satisfactory to the company but certainly not to the user. A more satisfactory way would be to construct the plates, if possible, so that these prime causes of trouble cannot arise, no matter what mistakes the attendant may make, or what emergencies the battery may be called upon to meet—within reasonable limits of course. To discuss all these prime causes in detail would require writing a treatise on the subject, but they may be summarized briefly, and their prevention will then suggest itself.

The chief evil effects are apparently caused by too rapid charg-

ing and discharging. With many of the favorite methods of avoiding the effects of high rates, the capacity and efficiency at such rates, both become so low that the user will be discouraged from discharging so fast, and the current will fall so rapidly that it will have little chance to do much mischief. Such methods are applicable only when rapid rates are never desired, but those cases are the exception, rapid rates, or at least a provision for them, being generally very desirable and often essential as in traction work for instance; such methods have therefore solved this problem only for a limited field. What should be done is to try to construct the plates so that they are adapted to high rates without a great loss of efficiency or capacity. It will be found that in the majority of cases in which the storage battery would be of special value, it is a question of *rate* rather than *capacity*, that is, a great horse power for a short time is more often required, than a large quantity of energy delivered at a slow rate; it seems from a number of cases, about which the writer has recently been consulted, that any capacity above that which is obtained at a one, two or three hour discharge is generally of comparatively little value.

To study the effects of rapid discharges it must be remembered that the acid is as important as the lead oxides; when its density falls too low there will be a lowering of the E. M. F.; Acid is withdrawn from the solution during discharge, hence the diluted acid in the fine pores of the active material must get out, and denser acid must get in; but the only force which does this is the difference between their specific gravities, and as this is very small, the force will be small and therefore the circulation will be slow, which in turn reduces the E. M. F. The chemical action will therefore be confined chiefly to the external surface, which is freely exposed to the acid, and the action then becomes so great per unit of surface, that white sulphating, or better, complete sulphating, takes place. If a rapid discharge is not to injure the plates nor lower the voltage by reason of the acid in the pores becoming too dilute, the circulation must be rapid; great porosity accomplishes this partly, but is attended by frailty and poor conductivity of the peroxide, which again results in a fall of the voltage. The ideal method would, therefore, seem to be a vertical lead plate to act as a good conductor with an extremely large surface and a very thin layer of peroxide on it, freely exposed to a large quantity of acid, which is capable of circulating rapidly. That such a plate may be made to have a greater capacity per pound of plate for rapid discharges and perhaps an equal one for slow discharges, as compared with the best thick, porous plates, has been shown by experiments. The great capacity is doubtless due to the fact that the active material is more completely utilized, as it is all close to the conductor and freely exposed to the acid. The capacity of such a plate will evidently be affected only slightly by the rate, and the loss of voltage and therefore the watt efficiency will depend more

on the conductivity of the lead, than on the acid becoming too dilute in the immediate neighborhood of the active material. To obtain high rates accompanied by good efficiency and capacity, there is little doubt that the best way is to use large freely exposed surfaces, rather than to try to resist the evil effects of high rates, mechanically.

In rapid charging, the acid becomes too dense in the pores of a thick mass of active material if the circulation does not keep pace with the demand; this dense acid softens the peroxide and there is a tendency to form gases when the proper chemical action cannot keep pace with the current. Both the softening of the peroxide and the mechanical effects of the gases are injurious. What was said regarding porosity and the ideal plate applies therefore also to the charging.

The negative plates being soft and tough, are not so easily injured, but unless the acid can circulate very freely, there will still be a lowering of the voltage like with the positive plates, and probably also a lowering of the ampere-hour capacity.

The contact between the peroxide and its conductor must be very good, for, if poor, then a white sulphate forms at the surface, which practically produces an insulating layer and disastrous effects are then inevitable. The ideal contact is obtained when the peroxide is formed on the lead electrolytically, as in the Planté processes.

The peroxide will insist on expanding during the discharge, and on contracting during the charge. It would be much better to accept this as an inevitable fact than to try to keep the material from obeying the laws of nature by forcibly confining it within an inelastic frame, as many inventors have attempted to do; the results of such an attempt have already been described. To hold a large mass of active material firmly in contact with a lead conductor, when one expands and contracts, while the other does not, or expands without afterwards contracting again—is a difficult matter. The best solution seems to be, to have the active material in the form of an extremely thin layer over a large surface, and formed from the lead itself, as this increases its adhering properties. If such a layer can be made porous, and if the surface is made up of small facets, there will be little tendency to buckling or scaling.

The gradual washing away of the surface of the peroxide, and the slow peroxidation and consequent disintegration of the lead support, seem to be absolutely unavoidable. Until, some preventive is found, if it ever will be, it seems wisest to accept the inevitable and acknowledge that the positive plates are perishable. To use any other metals or carbon, is out of the question; the addition of antimony to the lead seems to retard, but does not prevent peroxidation. The favorite method of trying to avoid the effects of disintegration, is to make the frames of the positive plates quite thick, thus prolonging their life. This, if not ac-

companied by other disadvantages, may be satisfactory for stationary plants in which the great additional weight is no hindrance, the only objection to it being the cost of the metal, which is no small factor in the total cost of the plate. But such a method is certainly not satisfactory for cheap or portable cells, and the gradual washing away of the peroxide remains the same whether the frame is heavy or light, provided that the surface exposed to the liquid is the same.

But there is another way of meeting those unavoidable effects of use, which has recently been applied, and which seems to be a much more rational and effective solution of this vexed problem, at least when lightness and smaller first cost are desired. Instead of making the positive plates heavy and expensive, they may be made very light, cheap and easily replacable; their life may then be shorter, but the battery will be as good as new whenever these perishable parts have been renewed; their life is soon known to the user and he can then readily determine for himself how much he must allow for amortization. Anyone who has urged the use of accumulators will appreciate the great value of being able to satisfy the user as to the amortization factor. A purchaser will believe you if you admit that the life of the perishable parts will be comparatively short, but he will not believe you if you say it will be long, even if you are telling the truth. But such a method, to be successful, requires that the old plates and sludge can be converted at a small cost into new plates; this it seems can now be done, and the writer believes that this alone will have a very important bearing on the outlook of the storage battery, at least for portable cells as are required for traction and many other purposes, or for both portable and stationary plants if the first cost is an important factor. Such a method becomes practicable only when the chief factor in the cost of the plate is the material, the cost of labor and forming being small.

For stationary purposes, in which the only objection to the weight is the first cost of the lead, good storage batteries have been used abroad with success for some time, provided the rates of charge and discharge are kept low. Assuming that the same storage batteries may be made in this country as well, the question which affects the outlook here, is then only one of the cost. But neither abroad nor here, does there seem to be a battery in the market in which the weight has been sufficiently reduced, and the rate sufficiently increased, for a really successful traction battery, the success of which has been demonstrated beyond dispute. It is here assumed that to the public and to railway companies, traction batteries are not a demonstrated success until a traction company which has no affiliation with the accumulator makers, finds it to its own advantage to use them in preference to other systems. That accumulator traction is the ideal system has been repeatedly acknowledged by good authorities, and that this field for batteries is very large and perhaps larger than that for station-

ary work, is likely. The large first cost and cost of maintenance of the overhead construction for trolley roads, the large power station required, and the threatened damages done by electrolysis, would doubtless turn the tables in favor of the storage battery for many long roads on which traffic is not too dense, and possibly also for many suburban steam roads.

It seems to the writer that the only batteries which have a promising outlook for this very trying work, are those which have a very large surface, very small depth of active material formed electrolytically, and a very free circulation of the acid. The lead frames should be made only thick enough for proper conduction, the batteries must be cheap in first cost, and the positive plates should be capable of being replaced comparatively frequently at small cost. They should be proportioned so that a discharge corresponds to one trip of the car—and only one. To claim as an advantage that a battery can run a car, say four trips, is mere deception, and to the intelligent engineer it is simply an admission that it can do no better. No one would think of carrying four relays of horses on a trailer of a horse car, and why should the equivalent be done with the storage battery unless it is that the battery can do no better, and that it cannot be discharged rapidly enough so that the capacity and weight may be reduced to that required to run only one trip. The ideal is certainly a single trip discharge. If the rate for a four-trip battery could be increased four times without materially affecting the capacity, its weight and capacity for a single trip discharge would evidently need be only one-fourth as great. The charging rate should also be equal in hours to the discharge rate, or else it will take a plant of more than two sets of batteries to a car.

These various ideals mentioned above would, have only a theoretical and not a practical interest, were it not for the fact that recent tests have shown that a near approach to them has apparently been reached; it is somewhat premature at present to say more until the results of the tests have been confirmed by practice.

The above discussion may be briefly summarized as follows: cessation of litigation and the development of the Planté type of cells, make the storage battery outlook in this country much brighter; the cost of a guaranteed storage battery seems in many cases to be too nearly equal to that of the direct generators to encourage their general adoption. A reduction in the cost would therefore open a large field, much larger than in proportion to the reduction; the renting of accumulators seems a commendable method for introducing them. Most of the diseases which storage batteries are subject to could be avoided or made much less disastrous by having large surfaces, small depths of active material and free circulation. The first cost would be reduced and the vexing question of the uncertain amortization, settled, by a light, short-lived, cheap positive plate and a cheap process of re-converting old into new positive plates. Storage batteries for slow

discharges have been a success abroad; a very large additional field would be opened by a light, cheap, rapid-rate cell.

The objection to a plate with a thin layer of active material, is that it may not retain its charge as well as one with a thick layer or pellets, but in most cases in which rapid rates are desired or cannot be avoided, the small loss in standing is probably more than balanced by the fact that the plates are not injured by rapid rates. As a rule, long periods between charges go hand in hand with slow discharges and less objection to great weight, while short periods between charges, high rates of discharges and lightness, usually go together.

In conclusion the writer desires to take this opportunity to make the following recommendations in the interest of engineers who may have to calculate accumulator plants:

That rates of charge and discharge be designated in *hours* and fractions, the current (or for power purposes, the watts,) during that time being considered to be kept constant. There can then be no mistake as to what is meant, as this represents the time in hours during which a cell will continue to give a practically constant current before the voltage falls below its limit.

That efficiences and capacities be always accompanied by the corresponding rate in hours.

That in giving an efficiency it should always be stated whether it is for ampere-hours or for watt-hours.

That for portable batteries intended for power purposes, the capacity be given in watt-hours instead of ampere-hours and that the weight given be that of the complete cell ready for use, as distinguished from the weight of the plates alone.

THE PRESIDENT:—We have a communication from Mr. Reckenzaun who has had a good deal of experience in storage battery matters which the author will kindly read.

COMMUNICATION BY FREDERICK RECKENZAUN ON "PAST EXPERIENCE WITH STORAGE BATTERIES."

A discussion of the storage battery question by this INSTITUTE is so appropriate that I sincerely regret that notice thereof reached me only a few hours before the opening of the meeting, due to my absence in Europe whence I have just returned. Being thus able to make only a very brief contribution, couched in general terms, I wish first of all to heartily endorse Mr. Childs' communication. While it contains much that has often been pointed out, advocated and demonstrated in the past, the arguments brought out in favor of the storage battery will bear repetition in view of the fact that the majority of engineers in this country have hitherto persisted in neglecting to fairly entertain them.

On the other hand, it must be conceded that there was cause for this neglect. Storage battery manufacturers in this country

concentrated their efforts rather upon the records of their selling departments than upon effecting lasting success for their products. The tendency was rather to show highest capacity and smallest weight and bulk, or at least to make claims for these features, regardless of the conditions to be met; and the selection of type, design of auxiliary devices, manner of installation and methods of operation were treated as if of secondary importance. Engineers and customers in general considered the price of storage batteries high, the manufacturers seemed to agree in that feeling and endeavored to economize in all that pertains to the outfit, to an extent which, as we know, proved detrimental all round. Through years of hard experience gathered by that policy, and contrary to the valuable suggestions offered by the work and success of our European colleagues, this state of affairs predominated until at last it is beginning to be recognized that no less skill, care, scrutiny and liberality is essential to success with the storage battery than with the construction, installation and operation of the plants it is to form an auxiliary of. The storage battery demands as much consideration as steam boilers, engines or the dynamos of an electric plant. It resents the assumption that it may be treated on a par with the coal bin as a storage arrangement.

European electrical engineers, who have long ago settled down to the placing of the storage battery in rank with other principal parts of an electric plant, and who are looking upon this country as being foremost in the quantitative application of electricity, wonder why we stayed so far behind them with the storage battery when all we needed to do was to copy from them and multiply. They have various types in successful use, and a number of manufacturing establishments are doing a substantial and prosperous business.

It may fairly be assumed, and the views which I gathered on the subject tend to bear out the assumption, that to the advantages offered by the storage battery, is to no small extent due the fact that direct current central stations continue to largely predominate over alternating current stations in Europe.

Mr. Childs very appropriately referred to the fallacy of taking the loss involved in the storage battery as the basis for the efficiency for the entire plant, where it only yields a portion of its output to the latter.

Such erroneous assumptions as this have helped to retard the progress of the storage battery here, but chief of all drawbacks unquestionably was the lack of durability, which, having now reached a much more satisfactory measure, should at last bring the success which we were so long looking for.

Discussion.

Mr. Townsend Wolcott:—Mr. President, I would first of all like to say that Mr. Edgar's communication is very important from the fact that he tells us what has actually been done with the storage battery. That is just exactly what we wanted. Instead of saying that such and such things can be done with the storage batteries, he says such and such things have been done.

In regard to Mr. Perry's communication the point that I wished to raise was in connection with the gas engine. It seems to me extraordinarily good work for gas engines, this consumption of 15 feet of gas per horse-power hour. I heard of a gas engine that ran 17 feet, but I learned by inquiring around that it was not a very durable engine or one that could be relied upon. May I ask what make of engine that is?

Mr. Perry:—I think that all the manufacturers in this country will guarantee 15 cubic feet, but in actual practice from 17 to 20 or more are required. I have used 25 cubic feet of illuminating gas in my calculations.

Mr. Edgar:—I would like to answer the questions Dr. Crocker raised; but before doing that, I desire to call attention to the point he made in regard to charging accumulators in series. He probably referred to the Popp system in Paris, which I also investigated with considerable interest. If that system is used, it is impossible to charge and discharge at the same time, unless the local systems of distribution are entirely separate; so that it could not by any possibility be used as we use systems of distribution in this country. All our network is connected together, and if our batteries are to be charged in series, it would be necessary to have two entire sets. This seemed to me to be the principal drawback of the system there, and it prevented its extension. It is impossible to keep the circuits entirely free from grounds, and the results would be that one system would have one voltage as compared with the ground, and the next another, and the next another, and it might go up to two or three thousand volts.

In regard to the question he asked in respect to cost, I have not the slightest objection to giving exact figures which will show upon what I base my statement. In the old type of station it was usually customary to figure that the entire steam plant outside of the real estate and the buildings—by steam plant I mean the generating plant in general—cost from $50 to $60 a horse-power. With the new type, high economy plant, it costs from $90 to $100 a horse-power. In our own experience we find that almost exactly true. In regard to batteries, our first battery was put in to give out 1,650 amperes on each side of the system. A 650 horse-power generating set gives out 1,333 amperes on each side. This, as a steam plant, would have cost $65,000. Our contract was for $44,000, and there were enough incidentals probably to bring it up to $50,000. This included

45 per cent. duty. I do not mean that if it was bought in this country it would cost the 45 per cent. less, for I understand that the cost of crude lead here is so much more, that part of it is eaten up irrespective of the question of duty. The second battery was double the size. That capacity would cost $130,000 if it had been a generating plant. Our contract was $64,000 for the battery. The former price included the switchboard, the latter did not; to that I add $25,000 to include switchboard and everything outside of the building. So that about $90,000 as compared with $130,000, and $50,000 as compared with $65,000 is the comparison I had in mind. I want to emphasize this one thing, and that is that we do not care anything about the kilowatt-hours of the battery for this particular comparison. Kilowatt hours have to do with operating. Kilowatt maximum has to do with investment; and we put it in for investment purposes. That is to say, as I have already said, we can with the same amount of capital put in more apparatus by using storage batteries than we can without. Now, if such apparatus has a capacity large enough to do that work which actually exists, we can actually save money by equipping one-third of our stations with battery and two-thirds with steam. I do not mean to say that considering the question of kilowatt-hours in general, for traction purposes, or for all the incidental purposes, that batteries are of course not very much more expensive than steam plants, and I tried to make this statement with particular reference to that special use of the battery.

Now, in regard to efficiency, our guaranteed efficiency is 75 per cent. I never have understood that a high rate of charge and discharge was going to interfere with the efficiency of the battery. It is undoubtedly going to cut down the capacity. With an hour-and a-half rate of discharge, the battery has only two-thirds of the capacity that it has at four, five and six hours discharge. The efficiency is the same, and I feel quite sure that the manufacturers claimed that we would get higher efficiency if we charged and discharged at maximum rates than if we did not. I personally know nothing about that, except what I am told.

There is another point that Dr. Crocker made, which appealed to me in exactly the opposite way from what it did to him, and that is the English practice of running a large number of small engines as compared with the German practice of using two or three very large ones. It was that particular thing that appealed to me for the value of the storage battery. When we realize that with the same type of engine, if you put in a 200 horse-power engine and one of 800 horse-power, you naturally get 10 per cent. better efficiency out of the large one, from the nature of its construction, and that the small engine is likely to run 15 to 18 hours a day; you will find that the inefficiency caused by the small engine is very much greater than the 25 per cent. battery inefficiency run for only two hours a day. So that

the actual economy of these small engines running under the best possible conditions is less than the economy of the large engines run under the best possible conditions, and a storage battery of 75 per cent. efficiency.

Then in regard also to the question of guarantee, I know nothing about what the American company guarantees. I have never asked the question. Our guarantee was for six per cent. of the cost of the cells. On the $44,000 contract I think the cells were put in at about $29,000. In the $64,000 contract the cells were put in at $59,000, so we are paying six per cent. on $59,000 worth of investment. There was a clause in the contract that if an American company was established, this should be reduced to four per cent., because this was done in Germany. I was informed by the manufacturers abroad that they were always willing to give a guarantee of four per cent., but that at least 75 per cent. of their customers refused it on the ground that it cost them but three.

MR. H. WARD LEONARD:—There is one use for storage batteries which has not been touched upon particularly, and which to me is perhaps one of its best applications, and that is in connection with the regulation of the speed of the motor, such as would be required for the operation of, for instance, elevators or street cars, as giving an abundance of means of securing variable electromotive forces for various speeds, and for reversals of direction. The point about storage batteries which is often raised to explain why the progress has been rather slow in this country has been the patent litigation, but I look upon that as merely an excuse for the slow development of an article which has not had a demand sufficient to develop it. I do not believe that any really meritorious article has been in the electrical field thus far which has been retarded in its progress by litigation, and the progress of the litigation which we have seen in the case of incandescent lamps, systems of distribution and electric street cars, while it may have cost a great deal of money for the litigants, as it unquestionably has, I do not think has tended to retard the progress of development—rather the reverse. In the case of storage batteries, the demand has not existed and their use has not given success, and that is the sole reason for the fact that they have not been used. As regards the cost per kilowatt, which is very largely the essence of the question involving economy, it seems to me that the figures that I have seen quoted, which make a favorable showing for the storage battery, take the maximum rates of discharge for the batteries that it is deemed safe to operate them at, and have taken the horse-powers of the engine at one-quarter cut-off. Now I agree with Mr. Edgar that the question of development of power for the peak of the load is one which is largely independent of the economy of production as compared with that for a very large portion of the total load which is below the peak. But it seems to me that in mak-

ing comparisons, we should consider the cost of the horse-power of steam generating machinery when operated at its maximum load, its maximum capacity, which will certainly be fifty per cent., without unduly straining any good boiler or engine above that for which it would have for the ordinary evaporations in the boiler, and a quarter cut-off in the engine, and I think that steam plants figured on that basis can unquestionably be installed for fifty dollars per kilowatt to-day, and ones which will be certainly more efficient in the production of a kilowatt than the development of a kilowatt by a storage battery, with the conversion losses and the lack of efficiency and capacity due to discharge at high rates. In that connection, I will say that it seems to me that it is unquestionable that there is a very marked difference in the efficiency—not only in the capacity, but in the efficiency—of the storage battery when discharging at high rates, and that a very large factor in the question of efficiency is the resistance of the battery, and the $C^2 R$ loss will certainly very rapidly increase with the rapid discharge. What I would like to find out, if we can, is: What is the cost per kilowatt, when the battery is discharging at the rate for which the manufacturers guarantee the six or ten per cent. depreciation which they have guaranteed, and the figures—although we have had figures that are on their face very convincing—do not give to me an explanation of the difference between the prices which we have been familiar with in the purchase of batteries and those which have been quoted. I have bought batteries and installed them almost every year since 1885, and I have never succeeded yet in buying a battery at a price approximating $50 per kilowatt, although, of course, I have not dealt in very large units, but I have received a discount from the list, which is as favorable as I think is given to customers in this country, because the instances that I had were ones in which the manufacturers were quite interested in seeing the applications made—I could not get the batteries at less than $180 per kilowatt when operated at the maximum rate at which they would make any guarantee. I think, that judging from the price list that we have in this country, it is impossible to expect to get batteries to compare in cost with steam plants, even when run at double the rate that they call the excessive rate of discharge, that is, even allowing that the battery shall be run at double the excessive rate. The cost of batteries, even those of the largest size—if I may judge from the prices of batteries of smaller sizes—would be at least $100 per kilowatt.

Now, one point as regards batteries in use in this country. It is a very familiar saying that we do not appreciate them over here; that they have been used abroad, and it is through a lack of interest in the matter, or a lack of appreciation of their points, that they have not been used here. But there is one thing which is very pertinent to my mind. I have been installing dynamos for a great many years, and I do not know one of them that I

have installed that is not running perfectly successfully and economically to-day and in good condition. And, as I say, I have been installing batteries nearly every year also, and I do not know one battery that is running that I have installed. That may be because I installed it, but there may also be some influence due to the fact that it is a battery. One of the best remarks about a battery that I ever heard was made by Mr. Edison to me. He said that "the blamed thing was wet," and I think that expresses a great deal electrically.

Personally, I am desirous of saying nothing except what is favorable of the storage battery; but I think that my views as to its applicability, and the reasons for applying it, differ from some others. I do not think that the storage battery is likely to be installed, when considering the question of cost in the light in which I presented it, because of its economy over the steam plant in dollars and cents, but I do not think that that is the thing to be considered. I think that Mr. Edgar has expressed it very well, and we all of us know how it is of the utmost importance that the service from an electric central station shall be perfectly reliable, and that the light shall be perfectly uniform, and the question of cost of the battery to my mind, and its efficiency also, is quite of secondary importance—if by the use of the battery they obtain absolute reliability of service and perfect uniformity of the light, and cannot otherwise—and I think that the battery may be installed in a station with a net saving to the station, rather than to go without it, when viewed from this standpoint; while I do not believe in the actual saving in dollars and cents in our central stations in this country, with the character of load diagrams that we have.

The figures which Mr. Edgar gave, I should like to ask questions about, as I think I must have heard them wrong. If I understood him, he said that the cost of a single battery was $50,000, when he considered the additional features that were necessary to get it installed, and I understood him to say that the capacity of that battery was 1,650 amperes at the full voltage of outside wires—1,650 amperes on both sides; well, allowing 250 volts for the outside conductors, unless I have made some error in my hurried calculations, it would seem that that is about 400 kilowatts, and if so, that would be about $12 a kilowatt.

MR. EDGAR:—One hundred and twenty dollars.

MR. LEONARD:—One hundred and twenty dollars—well, that seems to correspond with my figures better than I thought it did. Since it is $120 a kilowatt, which quite agrees with my idea of the cost, I do not see why it is maintained that it is so much cheaper in first cost than a steam plant.

MR. EDGAR:—I would like to say, in answer to Mr. Leonard's statement, that I do not think our battery rated at 1,600 amperes has any less factor of safety than an engine with one-quarter cut off; that is to say, that the battery is supposed to run regularly

1,600 amperes, and the engines that were put in at that cost are supposed to run regularly 400 kilowatts. It is possible that the engine would run double that. If you had dynamos that would run 800 kilowatts instead of 400, they would cost very nearly twice as much. There is no overloading of the dynamo to anything like the extent there is of the engine. The excess power of the boiler has already been discounted in its installation. On the other hand, the battery, although guaranteed for 1,600 amperes, is said to run 4,800 for fifteen or twenty minutes, if it has to, and I would not hesitate a moment to put that on if necessary. So I think the element of overloading in one, is about equal to what it is in the other.

Mr. Leonard:—The point which I should like to emphasize is that the guarantee has been upon a cost of $120. Of course, we all know that the batteries will give, with certain results, a very much larger rate of discharge. As to what these results will be, only the future can tell. But if they are worked at two or three times the maximum rate guaranteed by the makers, of course it is entirely at the risk of the owner of the battery, and I do not see any very good reason for supposing that they will act very differently from other batteries that have heretofore been overloaded. I do not quite agree with Mr. Edgar as to the fact that a dynamo cannot be operated during a period of half an hour or an hour, and at a very large amount beyond the amount for which it is guaranteed for continuous duty. It seems to me that in the case of large dynamos, the output could be very much increased for the matter of an hour or two without any detriment to the dynamo.

Mr. J. B. Entz:—I have recently spent a year in the factory of the Tudor company in Germany, and have had occasion to know what their practice is in that country and what their results have been. They have a great many large central stations which have been installed from ten to six years. The opinion of all engineers with whom I spoke on the subject were the same as those Mr. Edgar has expressed to-night. I have met engineers from Siemens & Halske and the Algemeine Electricitäts Gesellschaft, Schückert & Co., Oerlikon and other large companies, and whenever I started to criticise the battery in any way, they rebuked me by saying that it might be so in this country, but that the results were different there, and the results were very satisfactory. The company ships 60 tons of battery a day. In Hanover, where they have had an installation for six years, the efficiency was 83½ per cent. for the entire year's work, and the loss of energy but five per cent. of the total output. The company sells the batteries with the capacity specified for the different rates of discharge. The customer may discharge it in one hour, two hours or ten hours as he pleases, and it does not affect the guarantee. The purchaser has the option of taking the battery without any payment for guarantee for two years.

The company keeps it in perfect repair for that time. At the end of two years the purchaser can take a guarantee from the company for four per cent. a year for ten years, but very few of them care to do that. The actual expense of maintenance has been two and a quarter per cent. to the company. In that time they made considerable money out of that four per cent guarantee.

MR. J. R. WILLIAMS:—I would like to say that the efficiency of the battery, as Mr. Edgar stated, does not vary except within a very small fraction as the discharge rate increases; that is to say, a battery that would give a watt efficiency discharge at a ten-hour rate of 80 to 85 per cent, would still give a watt efficiency of 78 to 84 per cent if discharged at a two-hour or a one-hour rate. The capacity would decrease as the discharge rate increased. But if you take out a certain capacity at a high discharge rate, it would only require charging to the same extent as the amount of current that had been previously discharged.

MR. J. APPLETON:—There are one or two things about Mr. Perry's communication to which I would like to call your attention. He advocates the use of generators driven by gas engines for taking the peak of the load in central stations. Now in any station of a reasonable size this peak must be at least 400 horse-power. In order to take this with gas engines, it must be necessary at least to have two or more engines driving generators. I would like to ask Mr. Perry if he has tried to run dynamos in parallel with gas engines of that size. If he tried it once, I do not think he would be inclined to advocate it in this way. I notice Mr. Perry begins his communication by advocating the use of gas engines for electric lighting, and then goes on to say that he does not think there is a single case in this country where they have been successful. I think this must be due to the fact that he has never tried to use them in conjunction with storage batteries. The modern gas engine, as built in this country to-day, I do not think is very far behind the European gas engine. Germany is considered the home of the gas engine, but I think we are getting nearly as good results in this country now, as they are obtaining there. In fact, I know of many isolated plants which are working perfectly satisfactory with a combination of a gas engine and storage battery. Mr. Perry calls attention to the fact that in England, France and Germany a great many isolated plants and also central stations are using gas engines, but I venture to say that not five per cent. of the whole number are running without a storage battery in combination. Referring to his suggestion of transmitting power to outlying stations by means of gas through an iron pipe, even if the gas engine were available for taking the load in the outlying district during certain hours of the day, I think his calculations are wrong in one respect. He compares the price of the iron pipe to the price of copper mains.

Now I take it that if he has his iron pipe, he must have his copper mains as well; and having his copper mains, he might just as well use them to transmit current to the outlying districts and charge the storage battery, raising the pressure by a booster.

With regard to the general use of the storage batteries in this country, I think the previous practice has been wrong in this respect. The individual conditions of each case have not been considered. When an engineer considers any particular installation, he looks to the conditions, and puts down his generating plant to suit those conditions, and it must be done in the same way with a storage battery. There are storage batteries built to-day for certain purposes which ought not to be discharged above a ten-hour rate. Then again there are storage batteries built to discharge at a half-hour rate, because for heavy work and for regulation a battery must be capable of discharging at a very heavy rate. With regard to the question of regulation, recently I have had occasion to figure on a problem where there was an output of about 2,000 horse-power from one station; it was a fluctuating load, resulting in a variation in voltage of about 20 per cent.; by the application of a battery which would give about 350 horse-power at a one-hour rate, it is possible to keep that fluctuation down to a total variation of two per cent., and I think that is nearly as close as most engineers want. A great many of the speakers, or some of them at least, have said that the previous storage battery plants have not been a success, and in connection with this there is one point, I think, which has been quite overlooked. A storage battery will not show signs of distress when it is very heavily overloaded. You take a case of a dynamo and battery working in parallel on a two or three wire system; say some extraordinary conditions arise on the circuit, such as a short circuit; the battery would take a very great deal more than its share of the load. The generators begin to kick at once. The battery will take all that is wanted; and it is this very fact of your being able to get out of a battery nearly everything you want, whether the battery is built to discharge at a high rate or not,—that has been the ruin of a great many batteries in previous years.

MR. CHAS. BLIZARD:—We do not recognize the company Mr. Perry so mysteriously describes as "the leading storage battery company of this country."

Through an oversight, unintentional no doubt, Mr. Perry does not quote from a letter under date of June 11th, 1894, sent him by this same "leading storage battery company" in which the matter of maintenance is dealt with as follows:

"We will undertake to maintain installations of our accumula-
"tors when operated at normal rates, upon a basis that will limit
"the cost of perpetual maintenance to 10 per cent. per annum,
"upon the original cost."

If Mr. Perry had brought his communication up to date, he

might have quoted from the current edition of the catalogue issued by the storage battery company in question in regard to maintenance as follows:

"The company is prepared to undertake maintenance con-
"tracts under which they will guarantee that the total amount
"paid for renewals during the term of the contract, shall not ex-
"ceed 10 per cent. per annum on catalogue prices of the cells
"specified in the contract." The clause covering the return of the old material being omitted.

It is generally understood that retail prices are not maintained when wholesaling.

It is not a fact that the public has been led to understand by the battery company or its representatives that the guarantee offered means anything more or less than what is distinctly stated in the catalogue, and the fact that in the letter from which Mr. Perry quotes he was referred to the catalogue for terms of guarantee, is a sufficient refutation of his argument.

Mr. Perry's criticism would seem to cover the manufacturer who recommends the installation of a battery of capacity suitable to the work to be done, and who asks when giving a maintenance guarantee that the battery be worked within its normal limits and handled in accordance with the simple rules, which experience has proven, produce the best results as to efficiency and durability. I fail to see the injustice or hardship involved in these requirements.

Mr. Perry's statement that the guarantee holds good when the battery is cared for in exact accordance with the instructions laid down by the manufacturer, conveys the impression that an infraction of the rules would necessarily nullify the guarantee. While the selling company would undoubtedly have the right to withdraw, I do not know of a case in which such a course has been taken.

"The leading storage battery company of this country" does not anticipate that its business will be materially affected by Mr. Perry's alleged discovery of the difference between its nominal and actual guarantees.

MR. PERRY:—Replying to Mr. Appleton, I believe that he was right—that in most of the applications of the gas engine abroad, the storage battery is also used, as it is in connection with dynamos driven by steam engines. He speaks of the peak of the load requiring in the neighborhood of 400 horse-power. The largest gas engine so far constructed, so far as I know, single cylinder gas engine, is of 375 horse-power, with fuel gas; with illuminating gas it will go something over 400, perhaps 450 horse-power, and it has been repeatedly stated by English manufacturers that they were ready to make gas engines in 1,000 horse-power units whenever wanted. But it is customary, I understand, where the large units are employed, to use two-cylinder gas engines, so that we may have for instance an engine

of two cylinders, each of which would separately give 200 horse-power, and the explosions are so timed as to give an explosion once every revolution. There is an advantage in that since it makes the angular velocity of the armature more regular. Then in regard to the transmission of power by means of gas to an outlying station, Mr. Appleton suggested that we have the copper mains also. My idea was to supplant the copper mains with the gas mains, and while I suggested a six-inch pipe, that was assuming that we required that power continuously. With the storage battery the claim is that we may use a smaller conductor, and by charging for a long time, we can store up a large amount of energy to use when the demand is excessive. The same would apply to gas storage. You have your gas-holder there, and instead of using a six-inch main to carry that energy that distance, you might use a very much smaller one, and charge your gas-holder during the day, or during the hours of light loads, and your expense of transmission would be still less, and the interest on investment would be still less; and the other object in transmitting by gas to outlying stations was that the efficiency of transmission would be very much greater, at a distance of two miles even, than if you used a transmission of a thousand volts, which I suppose would be about as high as it would be proper to transmit current for the storage of energy in storage batteries.

In regard to Mr. Blizard's remark, in reading a paper before the National Electric Light Association, at Cleveland, I was jumped on by a member of the leading storage battery company of this country for some of my remarks in regard to the storage battery at that time. He distinctly stated at that time, if I recollect his remarks, that the cost of maintenance, guaranteeed charges, was 10 per cent. on the *price* of the battery, and this letter that I referred to and the catalogue—the catalogue was the one in force at that time—contradicts that statement flatly. This is the first opportunity I have had of replying to it. I have seen a later catalogue since that, and this also bases the guarantee on the catalogue prices. I also have in my possession the letter to which Mr. Blizard referred, but which I have not copied here. That letter, as I recall it now, is less specific than this one—this one being very specific—as it states here: "We "send you by to-day's mail our illustrated catalogue, and would "especially call your attention to the question of maintenance, "as contained on page 11." That seemed to be very specific, as to what their guarantee means. Their guarantee was on the catalogue price and not on the cost price; and at that time and in that place it is stated that: "In all cases of renewal by con-"tract, the old material becomes the property of the company "and must be returned to their works free of charge for carriage "or packing." Now the omission of that statement from the new catalogue does not convince me that they do not expect that. I know from the experience of some others—not my own experi-

ence—that when you ask for a battery for some particular purpose where the discharge is pretty rapid, or for some very unusual use, that the guarantee which they offer you, or that they print in their books, or that they talk about, no longer holds. They want a very much larger price for their battery, or their guarantee will be very much less favorable. And I admit that it is perfectly proper that they shall protect themselves; that that battery shall be used under certain conditions and in certain ways. They cannot guarantee a battery or a steam engine or anything else that is improperly used. But what I maintain is, that it is not economical under most conditions of central station practice, or at least where the demand is somewhat excessive in the way of discharge, to use the storage battery; that their prices are put up so high in order to give them a safe guarantee. Now there was a paper read at the Philadelphia meeting of the INSTITUTE, by Mr. Griscom, in which he stated that if you make your storage batteries large enough, the depreciation may be reduced to practically nothing. That we all know. So if you do make your storage batteries large enough, the company are perfectly safe in making you a guarantee of three per cent., or two per cent., or one per cent., if they choose; but your investment charges are very much larger under those conditions.

MR. E. T. BIRDSALL:—In regard to Mr. Perry's figures on the transmission of gas, he omits several important factors in the transmission of gas for that distance. In New York the subways are ventilated by pumping air through pipes, and they find that the loss of pressure per mile of 8-in. pipe, when delivering 12,000 cub.-ft. per hour, is 11 ounces per square inch. That is, starting with 16 ounces pressure, at the end of one mile the pressure is reduced to two ounces. That means, considerable power is used to pump that gas along, and that should be counted in the cost of transmission. Another factor is that the friction in the flow of gas in pipes depends greatly on the number of bends in the pipe; if it had a large number of bends or elbows, it would make a vast difference.

A third factor is the leakage factor. Every gas company in New York, except possibly the latest one, which has new mains, figured that the loss of leakage at the joints is about 10 per cent., and in that the loss of pressure in the electrical conductors is balanced at once.

In regard to the reason why batteries are not used more universally, it has always been my opinion, as the result of considerable experience, that all the first plants were too small for the work they had to do, and I will give two or three examples. One was a large private plant. A battery was put in, and it lasted six months under the use, and they put in a second one, about one-fourth larger, and that lasted about a year. The next one was about four times the size—that was about the time that I appeared on the scene—and that one lasted about three years, and

now we are contemplating putting in one about eight times the size to do the work. In that connection, I might say that I just let a contract to-day to replace one of the plants that Mr. Leonard mentioned. This is due to no fault of Mr. Leonard's. I laid out the original plant—he merely installed it. The original plant was 300 ampere-hours capacity. and the plant that takes its place is 800 ampere-hours capacity. That is as big as I could get the man to buy. If I had my way, it would have been about 1,600 ampere-hours. Though that is an unusual case. They have electric heaters, and that I think explains the whole matter. But this has been the great difficulty; a man would put in a battery, and as a rule it will be about one-tenth of the size necessary to the work, and the battery would fail in six months, and all batteries were the same in his eyes after that. In regard to guarantees, it is my present practice not to call on the companies for guarantees where I am reasonably certain of having a chance to look after the plant once in a while. The only experience I had with guarantees was not successful—the company failed before we had a chance to call on them.

Mr. A. E. Childs:—Mr. Edgar in his remarks spoke of the value of his battery in cases of rapid changes of weather. I was in Boston one day in September, and I happened to be in an office taking light both from his company and from the alternating current company in that city. At three o'clock a very black cloud passed over the city, and inside of five minutes possibly every light in Boston that was ordinarily in use was turned on, and there is no doubt that inside of five minutes Mr. Edgar's station had on its maximum load. His lights were absolutely perfect; there was no diminution in voltage. The lights were steady without a single flicker. The lights in the adjoining office were low; they were like red-hot hair pins, and were flickering. The alternating current company's representative stated afterwards that they had not even had time to fire up their boilers or to warm their engines before the load was upon them, and, so suddenly did it come, that it was impossible for them to take care of it. In Mr. Edgar's case, his lights were kept up to the proper voltage He had the maximum load of his station thrown on without five minutes' notice. In three-quarters of an hour the cloud scattered, the sun came out, and the lights were turned off. Those who had used the Edison light in that case were highly satisfied, and those who had the alternating current light were complaining that it was from twenty to twenty-five minutes before they were able to see or read by their electric lights. Gentlemen, this seems to me of itself an exceedingly valuable use of the battery for the central station. If installed for no other purpose, it gives to the company using such a battery an argument in favor of the storage battery that cannot be gainsaid.

Referring to Mr. Hering's communication, we find that on page 711 he states that "a purchaser will believe you if you admit

"that the life of the perishable parts will be comparatively short, "but he will not believe you if you say it will be long, even if "you are telling the truth." Later on he states that you may as well recognize that the life of a positive plate is short, and therefore you may as well build a battery that has a positive plate with a short life. His case seems to be like the case of electric meters in England, and the trouble which they had in introducing them. The original meters which were brought out were very scientific affairs, but the companies could not find people to use them. A happy thought occurred to one engineer to make the electric meters look as much like gas meters as possible, because the people were accustomed to seeing gas meters, and now it is an acknowledged fact that those meters which look like gas meters have a larger use in England than those meters which have special dial faces. Therefore it seems to me that Mr. Hering is working to satisfy the popular demand. He wants to produce a battery which has a short life, so that when he goes to a man and tells him he has a battery with a short life, that he wll be believed. He does not want to produce a battery with a long life, for he is afraid people will not believe him when he brings it forward.

On page 712 he goes on to relate that his ideal car is one which has a battery which will run only one trip. I would like to ask Mr. Hering what he means by one trip. It may be one mile, or it may be 20 miles, or it may be 50 miles. What is he going to do with his battery when he has a 50-mile trip to make, before he has an opportunity of renewing it? And he goes on to state with a dash of humor that it would be rather a curious thing to see half-a-dozen horses carried on a trailer behind a street car in order that they may be used as relays when the first horses get tired out. At first reading we almost fail to realize the keenness of his wit.

Mr. Perry states that he would not recommend storage batteries under any circumstances, but that he has a still more economical method, and he proposes to use the gas engine for a purpose for which none of us, I may venture to say, have ever seen it used before, and he states in the most positive language that it is a more economical method. I would ask him to refer to even one central station using gas engines to take the peak of their load.

Referring to his remarks on the guarantee which he describes here, of June, 1894, Mr. President, the world has progressed a great deal in the last eighteen months, and if Mr. Perry, knowing that his communication was to be read to-night, had taken the trouble to inquire what guarantees he could obtain *to-day* and *not last June* twelve-month, he would be able to find that the companies supplying batteries could guarantee to him a specific percentage depreciation on the cost of the elements, and not on the complete plant installed. He would be able to find that the rate at which the depreciation goes on was guaranteed to be very

small. It is astonishing, sir, to me at least, that a man will bring forward such statements as those, 16 or 18 months behind time.

In conclusion, I would state that the storage battery seems to call forth from engineers more prejudice than any other class of apparatus. It is my experience that certain engineers will tell you inside of 15 seconds, if you broach the subject to them, that they know all about storage batteries; that they do not want them at all, at any price; that they wouldn't have them if you gave them to them. If you put up a guarantee with government bonds at the back of it, they would not look at it. It seems to me, sir, that we must request engineers to show that spirit of enterprise, that spirit of investigation which they show regarding other classes of apparatus. We ought to expect from them that same spirit with regard to storage batteries, and that when they are approached on the subject of applying storage batteries to their central stations that they ought to take the matter in a spirit of investigation; and I am not wrong in saying that at present a large majority of them will not even consider the storage battery. They think they know all about it, and they think they know it would be of no use to them.

MR. CARL HERING:—Mr. Childs asks what is meant by one trip; one trip is the distance that a car travels from one power house to another or back to the first. I did not think the term required any explanation.

MR. CHILDS:—May I be allowed to ask Mr. Hering what the length of his trip is? That is the point I want to bring out. It varies considerably with different street car systems.

MR. HERING:—The length of a trip, of course, may vary very greatly. What I wished to emphasize in the paper was that the best possible arrangement of a plant would be to use a battery which will discharge in one trip, whatever the length of that trip may be; whether the trip is one of a few miles or of a hundred miles, the battery should be adapted to it. As a rule, the trips of a car in an ordinary city are comparatively short, much shorter in time than what would correspond to the "excessive" rate (four hours) of discharge of a certain well known accumulator; there are very few cars in use the length of whose trips, in time, is four hours or more.

Mr. Childs furthermore said something about my suggestion that it might be better to make cheap short-lived positives than expensive long-lived ones. My remarks, of course, apply chiefly to plates which deteriorate; if one installs a much larger battery than one which has just the right capacity, and discharges it at very low rates, the deterioration will be very small. But, as stated in my communication, I referred more particularly to rapid discharge batteries in which the deterioration, as one of the previous speakers has shown us, is very great; and in those cases I think

a cheap short-lived plate would be much better than one which is expensive and is intended to have a long life, but has not.

Mr. Childs in his paper states that the cost of a kilowatt-hour of battery is $37 to $40. Now, such a statement is very indefinite, and is of the kind which has misled so many. The statement is not complete unless the *rate* is also given, for it is very evident that if that accumulator would be discharged in one hour, the cost per available kilowatt-hour would be more than $37 or $40, showing that the *rate* ought to be given in connection with such a statement. I presume he meant that a ten-hour rate was understood; this means that a battery which will give a kilowatt (as distinguished from an kilowatt-hour) for ten hours costs ten times $37 or $40. If it is discharged at a higher rate than 10 hours, the cost per horse-power or kilowatt increases very much. Taking the catalogue of the company which he mentions, I find that for a four-hour rate the price per useful horse-power or kilowatt hour is increased about 25 per cent.; in other words, if you want a horse-power hour at a four-hour rate, it will cost 25 per cent. more than if you want it at a ten-hour rate.

Mr. Childs mentions an ampere-hour efficiency of 96.1 per cent.; that is very high, and I think it ought to be accompanied by a more explicit statement of how that efficiency was obtained. An efficiency, if it is as high as that, ought to be obtained by repeated successive discharges; or in other words, to be sure that the efficiency is correct, the accumulator ought to be discharged at least three or four times under exactly the same conditions. If it then gives an efficiency of 96.1 per cent. each time, the figure is correct; but unless it was discharged several times in succession under the same conditions, the figure which he gives can hardly be depended upon.

Mr. J. W. Lieb, Jr.:—Several of the speakers this evening have referred incidentally to one of the uses of a storage battery, to which I think more importance should be attached. With the constantly increasing application of electricity, particularly as a motive power, the conditions to be met by systems distributing electric current from a central station are becoming more difficult. This is particularly the case in residential districts where electric elevators, which are being introduced at a rapid rate, produce sudden and large fluctuations in the demand for current, at times when the steady lighting load is light. This variation of current demand causes fluctuations of the E. M. F. in the customers' service, dependent in extent upon the amount and distribution of the copper in the system of conductors, the proportion of steady to fluctuating load, and upon the dynamo capacity supplying current at the moment. The average demand for current during the hours of daylight in residential districts being light, the generating units supplying current must necessarily have proportionately small capacity, if they are to be operated economically. Under such conditions generating

capacity proportioned to carrying the average load when subjected to additional fluctuating loads, due to the inrush and accelerating current of starting elevators, would give rise to considerable variations in E. M. F. at the 'bus bars, and unsatisfactory lighting service. The addition of a storage battery is the effective remedy for such cases; a relatively small battery capacity taking up large fluctuations with but little fall in the 'bus pressure and with increased plant efficiency. The upper section of New York City, supplied from the mains of the Edison Electric Illuminating Company, is essentially residential in character, and since the beginning of 1893 the Edison company has had in continuous operation at its 53rd street station, a Crompton-Howell storage battery of a capacity of 2,000 ampere-hours, which in addition to other duties has most satisfactorily fulfilled the functions of a pressure equalizer as above outlined. Its effect upon the system is to reduce variations in the 'bus pressure to but $\frac{1}{8}$ to $\frac{1}{4}$ of what they would be with dynamo capacity alone in operation. Mr. Hering in his communication refers to the part which the chemist and the mechanical engineer have had in the development of the storage battery. I beg to differ with his unfavorable criticism of the work of the mechanical engineer in this connection, my own experience with many different types of batteries both in Europe and this country leading me to exactly the opposite conclusion. It appears to me that the lack of careful consideration of constructive details and substantial mechanical construction has contributed more largely to the failure of storage batteries in the past than lack of appreciation of the labors of the chemist. The wrapping of the plates in flannel, felt, asbestos, and similar materials, holding the plates together by rubber bands and similar devices, poor contacts at the electrical connections, lack of proper support for the plates, insufficient space between the bottom of the plates and the bottom of the tanks, and inadequate provision to prevent positive and negative plates from touching; these certainly are defects of mechanical construction. Yet how many failures could be directly traced to them. A statement of the important improvements that have been made in the construction of storage batteries within the past few years would, I think, show clearly a very substantial progress in all the details of mechanical construction. As much can hardly be said of the progressive work of the chemist in this direction, whose many investigations of the reactions involved in the electrolytic processes while of undoubted value have not developed any radical departures, while the tendency has been to revert to primitive types more substantial in construction and more carefully worked out in their mechanical details.

MR. CHILDS:—May I answer one point raised by Mr. Hering?

THE PRESIDENT:—Very briefly, Mr. Childs.

MR. CHILDS:—He referred to the increased cost of batteries

on the ten-hour basis. I would call attention to the fact, that a battery working at a ten-hour rate is much cheaper per kilowatt-hour than a battery working at a two- or three-hour rate, and if Mr. Hering will take the trouble to examine any of the published price lists, he will very readily be able to calculate the scale on which the cost is graduated.

Mr. Leonard:—I would like the privilege of answering one point which it seems to me is of the greatest importance, and that is this question of efficiency and high rates of discharge. As a matter of fact, a cell which I am thoroughly familiar with and have tested, has a resistance of a thousandth of an ohm and its discharge rate nominally is 25 amperes. To operate that under the conditions where a storage battery would show its greatest advantage, that is a rate of 125 amperes, so that it could be discharged about an hour and a half, the figures would have to be about as follows:—The capacity of the cells is 25 amperes at two volts. The $C^2 R$ watts lost when discharging at 25 amperes would be six-tenths of one watt, and the $C^2 R$ watts lost when discharging at the rate of 125 amperes would be 15 watts.

The President:—I think, as it is 11 o'clock, we had better adjourn. We are all very much obliged, I know, to the members of the Institute who have given the results of their experience, although that is a matter to be expected, as every member is supposed to tell everything he knows. But to Mr. Edgar, who unfortunately for us is not a member, I think we owe our very sincere thanks for the very clear and important communication he presented here to-night. A motion to adjourn is in order.

[Adjourned.]

Communicated After Adjournment by Nelson W. Perry.

The lateness of the hour and the very proper adjournment of the meeting prevented my replying at the time to several of the last speakers, whose remarks seemed to require a reply.

Mr. Birdsall questions my figures on the economy of gas transmission, citing the loss in head of the ventilating currents in the electrical subways, which he states as a drop from six to eight inches, initial to about one-half inch at a distance of two miles. These figures may be correct; but he must remember that the figures I gave were for a six-inch pipe that was free from obstructions, while he is citing two and one-half or three inch pipes which are more or less filled with conductors, offering an enormously greater frictional surface, and that these pipes open into manholes usually at intervals not exceeding 400 feet where eddy currents and leakage through the covers become important factors, and further that he is discussing air with a specific gravity of 1, and I illuminating gas with a specific gravity of, say, .45.

To show the effect of increased specific gravity, taking a large pipe, 12 inches in diameter and 3,100 yards long, we find that a discharge of 65,000 cubic feet at .4 specific gravity is reduced to 49,000 cubic feet at .7 specific gravity, and to 43,000 cubic feet at 1 specific gravity. He is correct in regard to elbows. My figures were for straight pipes. The effect of elbows is to increase the drop, the latter being also a function of the velocity. With ordinary velocities and a 90° elbow having a radius two and one-half times the diameter of the pipe, the following drops (in inches of water-pressure) have been calculated:—

Velocity of gas in feet per second.	Back pressure, caused by one bend, inches.
4	.0015.
6	.00336.
8	.00598.
10	.00934.
12	.0135.
14	.0183.
16	.0239.
18	.0303.
20	.0374.
30	.0841.
40	.149.
50	.233.

So that unless the velocity is very high, it requires a large number of bends of this kind to make a material drop in line.

To show the relative effects of bends, and the specific gravity of the gas in the illustration cited, viz: delivery of gas through a six-inch pipe under four-inch pressure at a distance of 10,500 feet, I find, by calculation, that the velocity of the gas in a straight pipe would be 8.3 ft. per second and the amount delivered would be 6,000 cubic feet per hour. To deliver the same amount with one 90° bend would require a pressure of 4.00598 inches, and with 10 bends 4.0598 inches. Or to express it in another way, the introduction of 10 bends would cut down the amount delivered from 6,000 cubic feet to 5,955 cubic feet, the pressure remaining at four inches of water. The pressure exerted by four inches of water is but 0.143 lbs. per square inch. It will thus be seen that an increase in specific gravity is more controlling than elbows in gas distribution, but that both of them may be overcome by an insignificant increment in the energy applied to transmission.

As regards leakage, there is no question that in some cases the leakage from gas mains reaches as high as 10 per cent. per mile, but a gas engineer who to-day would lay down a line of pipe that would leak to that extent, would be received by his brethren with about the same *eclat* as would the electrical engineer who would construct an electrical circuit that leaked to the same extent. I believe it to be a fact, that it is easier and cheaper to prevent leakage of gas at the pressures ordinarily used, than it is to prevent electrical leakage at customary voltages.

Mr. Childs quotes me as saying that I would not recommend storage batteries under any circumstances, which is correct as far

as it goes, but he omits the qualifications under which this was said, viz.: "There are some situations in which either convenience or extreme steadiness of current may be controlling, but "*where the question is purely one of economy*, I would not," etc. I think he will find it extremely difficult to prove that what I have said as to economy is not strictly true—so true, that it might be in many cases actually more economical as well as convenient to use storage batteries with gas engines, than to use steam engines without them,—the greater economy of the gas engine more than overbalancing the greater interest charges and losses in transmission and in battery by present methods. He knocks my argument all to pieces, however, by the profound statement that he "ventures to say that none of us have ever seen a gas engine used for this purpose before." Of course, if Mr. Childs "ventures to say" this, gas engines never have been so used. Mr. Childs, however, asks me to mention a central station using gas engines to take the peak of the load, and I will refer him to the Danbury and Bethel Gas and Electric Light Co.'s plant at Danbury, Ct. This is a small station, employing three 100 H. P. (nominal) gas engines, one of which is held in reserve. A series of five eight-hour Prony brake tests of the engines by Messrs. McDonald, Braine and Merritt, Jr.,[1] showed the production of an indicated H. P. on a consumption of 1.8 lbs. of coal. This is, I think, an exceedingly good showing for a station of this size, operated by units so totally unfit for the purpose, but by no means what it should be. The gas generator produced only 40 cubic feet of gas per lb. of coal, whereas it should have produced about double this of gas of a considerably higher calorific power. The mechanical efficiency of the engines, as given by Mr. Burchard,[2] averaged 87.31 per cent, and the thermal efficiency per indicated H. P. 18.61 per cent., and per brake H. P. 16.25 per cent. It is not a very rash assumption to say that had a more efficient fuel gas process been used, and the sizes of the units been better adapted to meet the load line, the K. W. output per lb. of fuel of this station, which for 182 days only averaged 435 K. W. hours per day, would have compared favorably with the best that has been reported to the National Electric Light Association. This was from a station having a daily output of nearly 23,000 K. W. hours, suspected by some to be Mr. Edgar's station at Boston.

I am placed in a somewhat awkward dilemma by the combined remarks of Messrs. Blizard and Childs, in regard to the letters from which I quoted, and from which I did not quote. Mr. Childs takes me to task for quoting a letter of such ancient date as June 18th, 1894, and Mr. Blizard takes me to task for not quoting one of still more ancient date, viz., June 11, 1894.

According to storage battery men, the storage battery is mak-

1. *The Stevens Indicator*, July, 1894.

2. Paper before Society Mechanical Engineers, April 10, 1895, by Anson W. Burchard.

ing such phenomenal progress, that the layman (and by layman I mean everybody, electrical engineers included, who are not professional storage battery promoters) can not keep up with it. If we make any statement as to the performance of the storage battery, they say, "Well, yes, but that was yesterday; you ought to *write* to us, however, and find out what we are doing to-day." It may strike some as being a little strange that when they are on their feet telling us to write for information, they do not give us the information then and there, but they never do.

As illustrating the great and rapid progress in the perfection of the storage battery, I would point to the two letters from the president of the company. In the letter of June 11th he wrote: "We will undertake to maintain the installation — — — on a "basis that will limit the cost of perpetual maintenance to 10 "per cent. per annum on original cost."

Within one week the battery had been so far improved that the president was enabled to write on June 18 that they would guarantee it for 10 per cent. per annum on the *list price*, provided we packed and sent back to the factory, at our own expense, the old plates.

Last February I estimated the cost of storage batteries at $35 per H. P. hour. Mr. Herbert Lloyd, General Manager of the company, corrected me by saying,[1] that my figures were 50 per cent. too high. If that were so, then the price at that time was $22.33, and the perfection of the processes of manufacture has increased during the nine months just passed so far, that they are to-day able to sell batteries, according to Mr. Childs, at from $37 to $40 per K. W. hour, which is equivalent to $27.75 to $30 per H. P. hour. There is nothing like numerical examples to fix upon the mind incomprehensible magnitudes. But why do storage battery authorities persist in confining their estimates of cost to K. W. or H. P. hours? Why do they carefully avoid kilowatts and horse-powers? Certainly not because they can quote K. W. hours at $37 to $40, and would have to quote kilowatts at $120, for that would be misleading. But in order that we may make a comparison of the relative investment charges, will Mr. Childs tell us what would be a fair figure upon which to base an estimate for a dynamo per K. W. hour capacity?

Considerable was said at the meeting about the lack of appreciation among engineers of the storage battery. Some speakers assigned one cause, and some another; but I think Abraham Lincoln came nearer to it than any of them in his account of a certain steamboat on the Mississippi. He said that it had such a little boiler and such a big whistle, that it had to stop to whistle.

May it not be that the reason the storage battery has not made more progress in this country is that its boiler is small and its whistle is big, and that it has been whistling too much?

1. *Transactions* Nat. Elec. Light Ass'n, 1895, and all of the electrical journals both American and English.

Discussion at Chicago.

A meeting of the Western members was held in room 1737 Monadnock Block on Wednesday evening, November 20. There were present about 20 members and 12 visitors. Prof. H. S. Carhart was elected chairman for the evening. The discussion of "Storage Battery Applications" was opened by Messrs. Arnold and Abbott, who read specially prepared communications. The communications presented at New York were referred, to but not read.

Communication by Arthur V. Abbott and Franz J. Dommerque on "Accumulator Economics."

It is true that the Europeans have made quite a large number of installations of cells, and with good success, but in this country this has not been the case as far as lighting is concerned. In the telephone service we have made of late rather an interesting application of small cells. It is in that service which formerly operated all the subscriber's transmitters at the various stations in the city by means of primary cells. A little more than a year ago it occurred to us to replace the primary cells by a small storage cell, charging the same continuously from the main office, excepting at the time when the subscriber was using the telephone in conversation. When the receiver is taken off the hook, the charging circuit opens, stopping the charging current for the time being, and allowing the local storage cell to discharge quite rapidly through the subscriber's transmitter for the purpose of conversation. Our installation has not been in service long enough to pronounce a conclusive opinion upon it as to the durability of cells of this kind. It is certainly very gratifying as far as it has gone. We have found that the maintenance of the local storage cell is less than that of the local batteries. As to whether the plates of the cell will last as long as we hope for, is a matter that future experience only can settle. In instances where the operation has been carefully made, and the installation properly and carefully attended to, we see no signs of deterioration in the plates. They seem as good to-day as they were 15 or 18 months ago. In cases of carelessness, either on the part of the manufacturer, or on the part of the users of the cells, it is unreasonable to expect that the cells will not suffer deterioration.

This, we regret to say, is the limit of our individual experience with the *durability* of storage cells. We feel that there is no question at all that they are a vast improvement, both from a service standpoint and from an economical standpoint, over the primary cell.

In the following we have taken what is perhaps a well-worn theme, and that is, the advisability, or, rather, an instance of the advisability of storage battery installation by comparing the cost

of an electric lighting plant capable of supplying the entire city of London, as indicated by this diagram, which was taken a little over a year ago, with a steam plant alone, or with a steam plant with accumulator-regulation.

In the electrical installations, whether they may be for lighting or for power distribution, electricians have been seriously hampered so far, from the fact that their station must be sufficient to supply the maximum demand that can be put upon it. We have no form of reserve. In gas works the retort plant may be comparatively small and run 24 hours for 365 days in the year. The break of gas in the holders is reasonably inexplosive, and in the holders we may store up 22 hours out of the 24, the breaks of the retorts to it use the other two hours. With water power we may build a dam, and the stream flowing into it may increase the reservoir capacity all night long, although the wheel turns but eight hours out of the 24. In other forms of manufacture we are able to store up a sufficient quantity of material for a sudden or unusual demand during a short period; but in electrical installation this cannot be done. The demand, as indicated in the diagram, is exhaustive between, say, 4 and 7 P. M. During that time the current rises to 11,600 kilowatts. During the other 21 or 22 hours of the day it is a comparatively small demand.

There have been in Europe a good many plants that have adopted storage cells for the purpose of equalizing the load line, and for the purpose of reducing the investment and size of the steam plant.

The European installations have, as far as we know, been uniformly successful. Why it is that they have not been introduced into this country to a greater extent, we are not aware. With the exception of the Edison company, there have been almost no installations of that character.

The European engineers have investigated load diagrams thoroughly and succeeded in cutting off the peak. How did they do it? Simply by developing accumulators. They brought it down to such a point that, for instance, in the Hanover station, the accumulators are kept in perfect order by the manufacturers, for the consideration of four per cent. on the original cost, for ten years, and are handed to the city at the end of the ten years in first-class service condition, the efficiency of the accumulators being 96 per cent. in ampere hours, or 78.4 per cent. in watt hours.

In order to give an idea of the ratio of capital expended on accumulators, to capital expended on the rest of plant, the rating of the property as it stood at the end of the year 1893–1894 may be written down.

Lot and building	628,075.71 marks.
Machinery	296,023.28 "
Accumulators	125,000.00 "
Line	538,866.87 "
Water facilities	44,968.01 "

Tools, instruments and furniture	29,489.80	marks.
Electricity meters	60,600.89	"
Street lighting	15,758.07	"
Stores	16,489.4	"
Miscellaneous	13,439.64	"
Interest and stock market loss	128,634.08	"

In the case of Dusseldorf, the accumulators range higher yet, while the total installation cost is put down at 2,260,000 marks. The accumulators alone are credited with 280,000 marks.

Fig. 1 shows the combined output of the whole London central stations during the 24 hours ending at 6 A. M. on the 20th of December, 1894.

The correct level to base the calculation upon, is the day of highest load, and it will not be far out to choose the diagram of the 20th of December for this purpose.

The load curve shows a maximum load of 11,600 kilowatts, or

$$\frac{11,600,000}{740} = 15,700 \text{ H. P.},$$

and a minimum load of 800 K. W. equals

$$\frac{800,000}{740} = 1,080 \text{ H. P.},$$

the load factor being 33 per cent.

First, it may be ascertained what would be the expense if regulation was performed by shutting down part of the plant; afterward the expense with accumulator regulation will be calculated, and the comparison between the two obtained values will be the decision as to which system of regulation is preferable. In the first instance the plant has to be fitted up with machinery capable of supplying the demand at maximum load = 15,700 H. P. From the load diagram it will be seen that during about 14 hours, the load does not exceed 3,000 H. P. to any extent. This is of great importance for the choice of units. Choosing five units at 3,000 H. P. each, would take care of the maximum load also, as for a very short time during the day the engines and dynamos could be overloaded a trifle; the necessity of doing this would only occur in a few winter days anyhow.

The items required to determine the expenses would be:

Cost of fuel per year.

Cost of labor.

Cost of supplies and repairs.

Interest and depreciation on plant.

It has been ascertained by Mr. Fritsche that the average load throughout the year is 16.375 per cent. of the maximum load, hence,

$$\frac{15,700 \times 16.375}{100} = 2,571 \text{ H. P. per hour},$$

or,

$$2,571 \times 24 \times 365 = 22,521,960 \text{ H. P. per year};$$

the amount of coal used per H. P. hour being about 1½ lbs. For such large units as are used in this case, it would require 22,521,960 × 1½ lbs. per year, but to maintain banked fires, when part of the boilers are shut down, and bring the fires to average working condition again, an allowance should be made, which in the present case, where 3,000 H. P. are always required, does not amount to very much. Assume an addition of 20 per cent. on the 3,000 H. P. for the 14 hours, or 600 × 14 × 365 = 3,066,000 H. P. hours per year. The total H. P. hours would equal 22,521,960 + 3,066,000 = 25,587,960 H. P. per year, and the amount of coal used would equal 25,587,960 × 1½ = 38,351,940 lbs., or 19,176 tons (of 2,000 lbs.). The price of coal per ton may be taken at $2.25, then the cost of fuel per year equals 19,176 × 2.25 = $43,146.

The cost of labor is determined as follows: One attendant is required per unit, or five in all, at 25 cents per hour, equals an expense per hour of $1.25. Ten firemen and two helpers at the same rate, or an outlay of $3.00 per hour. This fixes the cost of labor at $4.25 per hour. Add for superintendence $1.50 per hour, obtaining a total of $5.75 per hour, or $5.75 × 8,760 = $50,370 per year.

Cost of supplies and repairs is found, applying Dr. Emery's results obtained from the cotton mills of Fall River, as 22,501,960 × $0.0008 = $18,000 in round numbers.

It remains yet to determine the interest and depreciation.

Money is obtainable at five per cent., and the amount necessary to provide for depreciation should not be any more; therefore 10 per cent. is assumed. The cost of steam plant, taken at $64 per H. P. (Emery's value) + ⅛ surplus power, a plant of

$$15{,}700 + \frac{15{,}700}{8}$$

equals in round numbers 17,700 H. P., as required which will cost 17,700 × 64 = $1,132,800, 10 per cent. of which is $113,280. The cost of dynamo, switchboard and accessories may be taken at $35 per K. W., or $25.90 per H. P.

The cost of 15,700 H. P. will be 15,700 × 25.90 = $395,000, the interest and depreciation of which, on the basis of 10 per cent., will amount to $39,500.

The total expense, therefore, per year will be $43,146 + 50,370 + 18,000 + 113,280 + 39,500 = $264,300 for regulation by shutting down part of the plant.

To calculate the expense for accumulator regulation, the load diagram has to be studied. The kilowatts found by integrating the area below the load curve gives the watt hours to be delivered to the line; this is found to be 100,800,000 watt hours. The engines in this case have to generate an additional amount to make up for the loss in the accumulators. The total amount may be designated for the present by x watt hours; x watt hours

may have to be supplied by the accumulators, and z watt hours by the dynamos in 24 hours; z may be the effect to be produced by the dynamos in watts. If the efficiency of the accumulators is taken as 75 per cent. (which is not too high by European experience), $\frac{100}{75}\,y$ or $1\frac{1}{3}\,y$ have to be given to the accumulators to enable them to give y to the line, hence $\frac{1}{3}\,y$ is lost in the accumulators: z will, therefore, be equal to $100{,}800{,}000 + \frac{1}{3}\,y$. If there was no loss in accumulators, z would equal 100,800,000, and

$$z = \frac{100{,}800{,}000}{24} = 4{,}200{,}000 \text{ watts.}$$

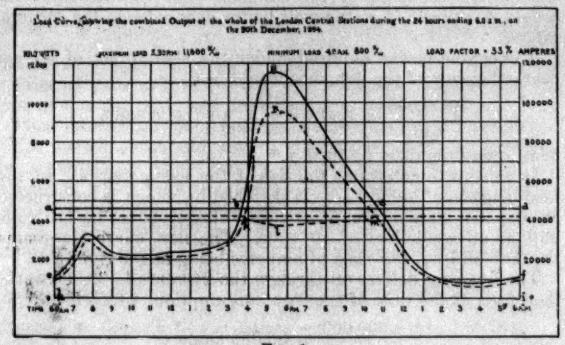

Load Curve, Showing the combined Output of the whole of the London Central Stations during the 24 hours ending 6.0 a.m., on the 30th December, 1894.
KILOWATTS
MAXIMUM LOAD 11,320 KW. 11,800 %
MINIMUM LOAD 4,244 KW. 800 %
LOAD FACTOR = 35.5 %
AMPERES

FIG. 1.

This value is plotted in Fig. 1 as a dotted line; this line cuts off the peak and would give the dynamo rating in watts, if there was no loss in the accumulators; by integration this amount is found to be 29,400,000 watt hours. This value inserted in the equation:

$$z = 100{,}800{,}000 + \tfrac{1}{3}\,y$$

gives

$$z = 100{,}800{,}000 + 9{,}800{,}000 = 110{,}600{,}000 \text{ watts per day,}$$

and

$$z = \frac{110{,}600{,}000}{24} = 4{,}608{,}333 \text{ watts.}$$

This value is plotted again in the diagram, and the new value for the area of the peak found as 28,800,000 watt hours. Inserting this value again in the equation, the value of z is found this time as:

$$z = 100{,}800{,}000 + \frac{28{,}800{,}000}{3} = 110{,}400{,}000 \text{ watts per day,}$$

and

$$z = \frac{110{,}400{,}000}{24} = 4{,}600{,}000 \text{ watts.}$$

Now the value of 4,200,000 watts for z would render z for the dynamos too low, as no loss in accumulators was assumed, and $z = 4{,}608{,}333$ watts makes it too high, as the accumulator loss is taken in that case too high, the value of $z = 4{,}600{,}000$ is nearer to the correct value, and may be taken in the present case for the correct value, though it is possible to come closer to the correct value yet. Plotting a line corresponding to 4,600,000, which may be a, b, c, d, then the area e, b, c, f, i, h gives the watt hours delivered by the dynamos direct to the line; the area a, b, e plus c, d, f, the watt hours, charged into the accumulators.

The engine power required under the assumption of 90 per cent. efficiency of the dynamos would be:

$$\frac{4{,}600{,}000}{740} = 6{,}215 \text{ H. P.} - 10\,\% = 6{,}836.5,$$

or in round numbers 6,850 H. P.

It remains to determine the size of the accumulators. In the load diagram a dotted curve is sketched in, which is constructed on the assumption that the lamp voltage should be 110 volts with an allowable loss of 10 volts. The new curve represents the ampere load, the scale of amperes being at the right side.

The dynamos deliver all through the 24 hours 4,600,000 watts, therefore, at the time of greatest consumption, which is at 5:30,

$$\frac{4{,}600{,}000}{120} = 38{,}333 \text{ amperes}$$

will be the dynamo current, and the highest discharge current is obtained by subtracting these 38,333 amperes from the total current at this time: 96,666 — 38,333 = 58,333 amperes. The total current at 4 P. M. is 50,000 amperes, corresponding to a loss of

$$\frac{50{,}000 \times 10}{96{,}666} = 5.2 \text{ volts.}$$

Hence the dynamo current equals:

$$\frac{4{,}600{,}000}{115.2} = 39{,}930 \text{ amperes.}$$

At 10 P. M. the total current is again 50,000 amperes, and we obtain at this time the dynamo current also = 39,930 amperes. At 8 P. M. the total current is 70,000 amperes, as seen from the curve, corresponding to a loss of

$$\frac{70{,}000 \times 10}{96{,}666} = 7.23 \text{ volts.}$$

Hence,

$$\text{The dynamo current} = \frac{4{,}600{,}000}{117.23} = 39{,}240 \text{ amperes.}$$

Plotting these values obtained for the dynamo current at the different hours into the diagram, the curve k, l, m, n, if integrated, will give the accumulator capacity = 240,000 ampere hours. From the price list of the Electric Storage Battery Company, a cell of 5,000 ampere hours capacity costs $375. If there is such a great quantity needed, the price of $375 would be reduced at least to $350.

$\frac{240{,}000}{5{,}000} = 48$ cells in parallel would be required.

The potential of one cell is 1.85 volts, and as a maximum of 120 volts is required, $\frac{120}{1.85} = 65$ cells as needed, hence the total number of cells $= 65 \times 48 = 3{,}120$.

Price of cells $= 3{,}120 \times 350 = \$1{,}092{,}000$; interest may be fixed at five per cent., and depreciation at five per cent.

Then interest and depreciation on accumulators = $109,200.

For switchboards and meters a first cost of 10 per cent. on the accumulators would not be too low, the interest and depreciation on which may be taken at 10 per cent., then the annual expense for switchboard and meters equals $10,920.

The steam plant required was found as 6,850 H. P. Taking again the cost per H. P. at $64 + \frac{1}{8}$ surplus power would give:

$$64\left(6{,}850 + \frac{6{,}850}{8}\right) = 7{,}310 \times 64 = \$467{,}840;$$

interest and depreciation at 10 per cent. would give $46,784.

The dynamo plant, figured at $25.90 per H. P., would amount to $6{,}850 \times 25.90 = \$177{,}420$; 10 per cent. interest and depreciation gives annual expense for dynamos and switchboard as $17,742.

The amount of coal used per annum would be $6{,}850 \times 24 \times 365 \times .16375 \times 1\frac{1}{2} = 12{,}282{,}887$ lbs., or 6,141 tons of 2,000 lbs. Then taking the cost per ton again at $2.25, the expense for fuel would be $6{,}141 \times 2.25 = \$13{,}820$.

Cost of labor will be found as follows:

Three attendants at 25 cents per hour, expense per hour $.75; four firemen and one helper, at same rate per hour, $1.25; plus $1.50 for superintendence, which makes a total of $3.50 per hour, or $3.50 \times 8{,}760 = \$30{,}660$ per year.

Cost of supplies and repairs equals $6{,}850 \times 24 \times 365 \times .0008 \times .16375 = 5{,}550$ per year.

Adding all determined expenses, 109,200 + 10,920 + 46,784 + 17,742 + 13,820 + 30,660 + 5,550 = $234,676, against $246,300 found for regulation by shutting down part of the plant.

MR. F. J. DOMMERQUE:—I would like to instance a few points which I have noted in Germany. I have had occasion to meet several engineers who had charge of large accumulator stations in Germany about three years ago, and asked them their saving in their special stations, and found it not less than 30 per cent. I think that further savings could be effected, as the accumulators could be placed in cellars, or in the third or fourth stories of buildings, and so the outlay for buildings would be decreased. In one city I found that the accumulators were placed two or three miles from the station itself. My experience has been that the first outlay was considerably higher than the entire steam plant, and it was feared the first time it would not pay at all, and that the city would have considerably money to pay in addition to the income. It was figured out, and it was shown, that where accumulators are used to any extent, that it was cheaper to use them than it was to use the battery engines.

MR. CARL K. MACFADDEN:—I have a set of accumulators about 180 in number, located at a large gas engine central station in this city, and although I cannot say the battery is taking a great deal of our evening load, I have every reason to believe that if we had the right size of storage battery auxiliary, we would get some excellent results. We have installed an electric light station of over 400 horse-power in gas engines here in the city, and have found in a number of cases that although the battery plant has a capacity of not over 600 ampere-hours, it has helped us in a wonderful way when we have had trouble with an engine, and we have found it especially valuable in very light loads, when it would not pay us to run the smallest engine, which is of 80 horse-power. I can see a very good chance of supplying storage batteries in certain stations, such as I have spoken of, and I notice that it is being taken up to an ever-increasing extent in European stations. With the improved methods of manufacturing storage battery plates, and with the guarantees which some of the larger manufacturers are now able to give, I see no reason why they should not be used to as correspondingly great an extent in America as in Europe. In small gas engine stations, there has been considerable attention paid to storage battery auxiliaries. In large gas engine stations, storage batteries will be used in conjunction with improved types of gas engines, so as to keep the engine up to its best load, for the gas engine ought to be loaded up to its rated load to get its best results, the same as the ordinary steam engine.

MR. LUDWIG GUTMANN:—The reason that the storage battery business is so well developed in Europe and almost neglected in America can, no doubt, be traced to the fact that in Europe until within the last year or two, with few exceptions, all installations were of the low tension continuous current type. In many places, especially in theaters, it was compulsory to provide means, such as storage batteries, to prevent a sudden giving out of light,

due to defects in machines. On the other hand we find in America the majority of installations of the high tension alternating current order. I remember having seen stations some eight or nine years ago in England, for instance, that of the Alhambra Theater in London, in which the engine and dynamo capacity were selected smaller than necessary for the total output. The balance was installed in storage batteries, which were charged during the day and helped the two Edison dynamos at night to supply the light, while they were also used in the day time to supply the few lamps that were needed all over the house.

Here in America there was not such a great need for storage batteries, or, if it existed, it was not satisfied because capital was afraid of master patents such as Brush, Faure and Planté, and, no doubt, a pressure was exercised by the companies controlling these patents on others who wanted to venture into the storage battery business.

However, now the fundamental patents having expired, we will experience a greater activity in the development and manufacture of storage cells. The need for such cells has been growing steadily, and I believe that no great stimulation is required for their introduction.

In Europe circumstances aided the development of this branch, and among these were the prohibition of overhead wires in many cities, and the use of too great engines, which would have needed considerable valuable space, heavy foundations, also large space for receiving and storing coal. The battery was a means of permitting the use of a smaller engine and dynamo and storage of the energy, preparatory to the heavy demand.

It seems to be an American trait to neglect one undeveloped branch of the business at the expense of another which is advanced to the greatest extent. I wish to remind you of the sudden start of many engineering firms into the high tension alternating current work in 1887 and 1888; then the vigorous attack on the railway motor and its development, and now since it has also passed into a field of stability, there is a unanimous attack prepared to solve the storage battery problem. The fruit is worth looking for, as the usefulness of the storage battery is far greater than may be thought for at first sight by many. It will not be restricted to low tension continuous current work, but it will be used in central station distribution by means of high tension single and pluri-phased alternating currents which are changed by rotary transformer into continuous currents to charge the batteries with the surplus energy the dynamos develop at the time of light loads.

MR. SHEEHY:—With reference to my experience with storage batteries in connection with signal work, I will say that it is of very recent date, and, in fact, I might say that the various classes of batteries have been used. I had to do with the first one used

in this country, as well as those brought from Europe. I do not think there is anything I can say to add to the discussion this evening. So far as my faith in storage batteries is concerned, I believe very emphatically in its use, and would even go further in my endorsement than any one here to-night has gone.

MR. M. H. GERRY, JR.:—I am much interested in the application of storage batteries, and have listened with great pleasure to the remarks I have heard this evening. I am profoundly impressed with the desirability of using storage batteries in connection with fluctuating loads for both lighting and power purposes, provided that batteries can be found which will satisfy commercial conditions. Much has been written in the past in regard to the great losses and rapid deterioration of storage batteries, but I cannot help thinking that the results may have been partially due to improper handling, or inefficient apparatus for regulating the charging or discharging currents. If a storage battery can be obtained, costing not more than the same kilowatt capacity of a first-class prime mover, having a commercial efficiency of 75 per cent., and a cost of maintenance not greater than six per cent. of the investment, then such a battery can be used in a great many power stations with advantage in point of economy. It is only a question now, whether such a battery can be obtained, and a great many practical engineers are looking with considerable interest in the direction of storage battery manufacturers.

I have listened with pleasure to the gentlemen here to-night who have had large experience in this attractive field, but regret that they have not said more in regard to deterioration, and to the maximum discharge which batteries can safely stand. I would like to add a word in reference to the rating. The present method of stating the capacity in kilowatt-hours or ampere-hours is not altogether satisfactory. More important than the total capacity in the application to fluctuating loads is the maximum rate at which a battery can be repeatedly discharged without seriously damaging it. A kilowatt rating representing this maximum discharge would be of more value in cases of this kind than the kilowatt-hour or ampere-hour rating above referred to.

MR. B. J. ARNOLD:—The first thing which I wish to call attention to is the discussion of Mr. Perry, in which he advocates the use of gas engines for taking the peak of the load, or the fluctuating load of electric plants, instead of batteries. He states that under no circumstances would he recommend the use of batteries, for the simple reason that the gas engine will be found more economical. I think this is rather a broad statement, and one which the advocates of this system will have some difficulty in substantiating, for the reason that gas engines working on variable loads are extremely uneconomical, and not only are they uneconomical, but they are very sensitive to changes of load. If the load on a gas engine changes suddenly, it is liable to re-

quire immediate attention on the part of the operator to keep it in operation, as indicated by my experience with some engines. It is probable that certain makes of engines are more reliable in this particular than others, but under any circumstances it is almost imperative to have an attendant near a gas engine while it is in operation, if working on variable loads. For this reason and the fact that the gas engine is uneconomical at light loads, the plan of placing gas engines in different localities over which a system of electrical distributing mains were being operated, in order to help out the heavy loads at distant points would be impracticable, as each engine would necessitate an attendant to start the engine at the time that the line required extra power. On a railroad circuit, this demand is constantly changing from the negative to the positive factor, and if a gas engine is used, it would be running a portion of the time with practically no load, and the next instant with excessive overload. A battery installed in the same locality would receive the excessive current delivered to it when the demand on the line was light, and discharge it into the line when the demand was heavy, automatically, thus storing the energy and giving it back when needed, without the services of an attendant. The figures given by Mr. Perry, showing the consumption of gas at various loads, show that the engine consumes over three times as much gas per H. P. when running at one H. P. as it does at 12 H. P., its rated capacity, and in railroad work the engine would be thus running a large portion of its time, and I believe that the results would be far from satisfactory to the company operating such a system, especially if there were any number of engines in operation. A gas engine could be installed as an auxiliary to a central station to carry the peak of the load if it was comparatively steady, as is the case in lighting plants, but my judgment is that it will be much better economy and engineering to put in another steam engine, which could be driven from the same battery of boilers, steam piping, etc., already in the station, than to install a gas engine and necessitate the attendance of engineers especially skilled in handling both steam and gas engines. There is no question in my judgment but that a gas engine plant, installed properly and run on producer gas, will deliver a K. W. hour on the switchboard for less money than a steam engine plant can do it, but in order to do so, the engines must be run at practically a constant load. Such a plant, working in conjunction with a battery auxiliary, I believe to be the most feasible solution of the power station question, and one which we will probably come to in this country in the near future.

Probably of more interest than any general discussion of this question will be some specific cases showing the application of batteries. I have brought with me to-night some load diagrams of stations in which batteries will be installed. The first, shown in Fig. 2, represents the diagram of a railroad plant operating

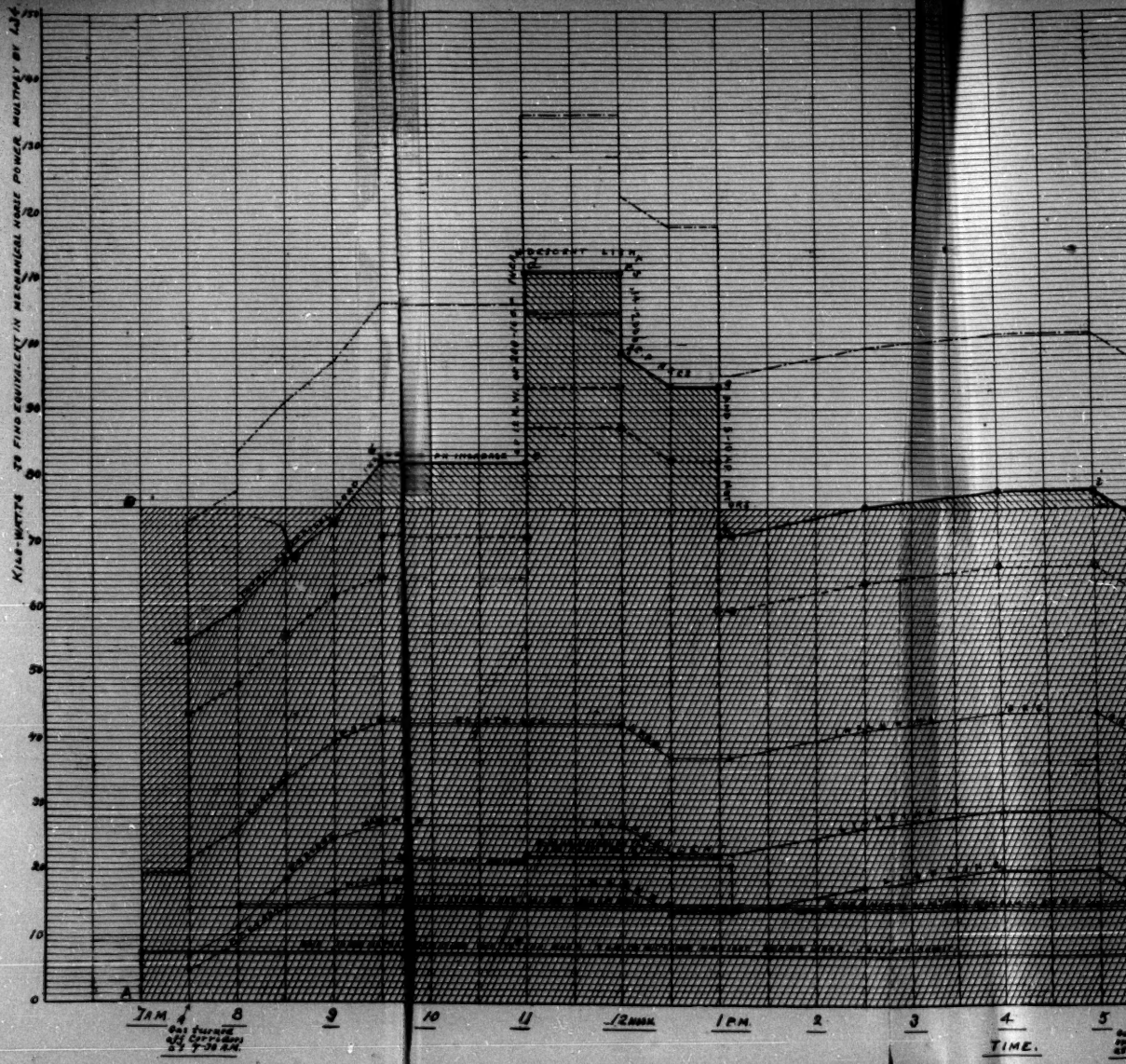
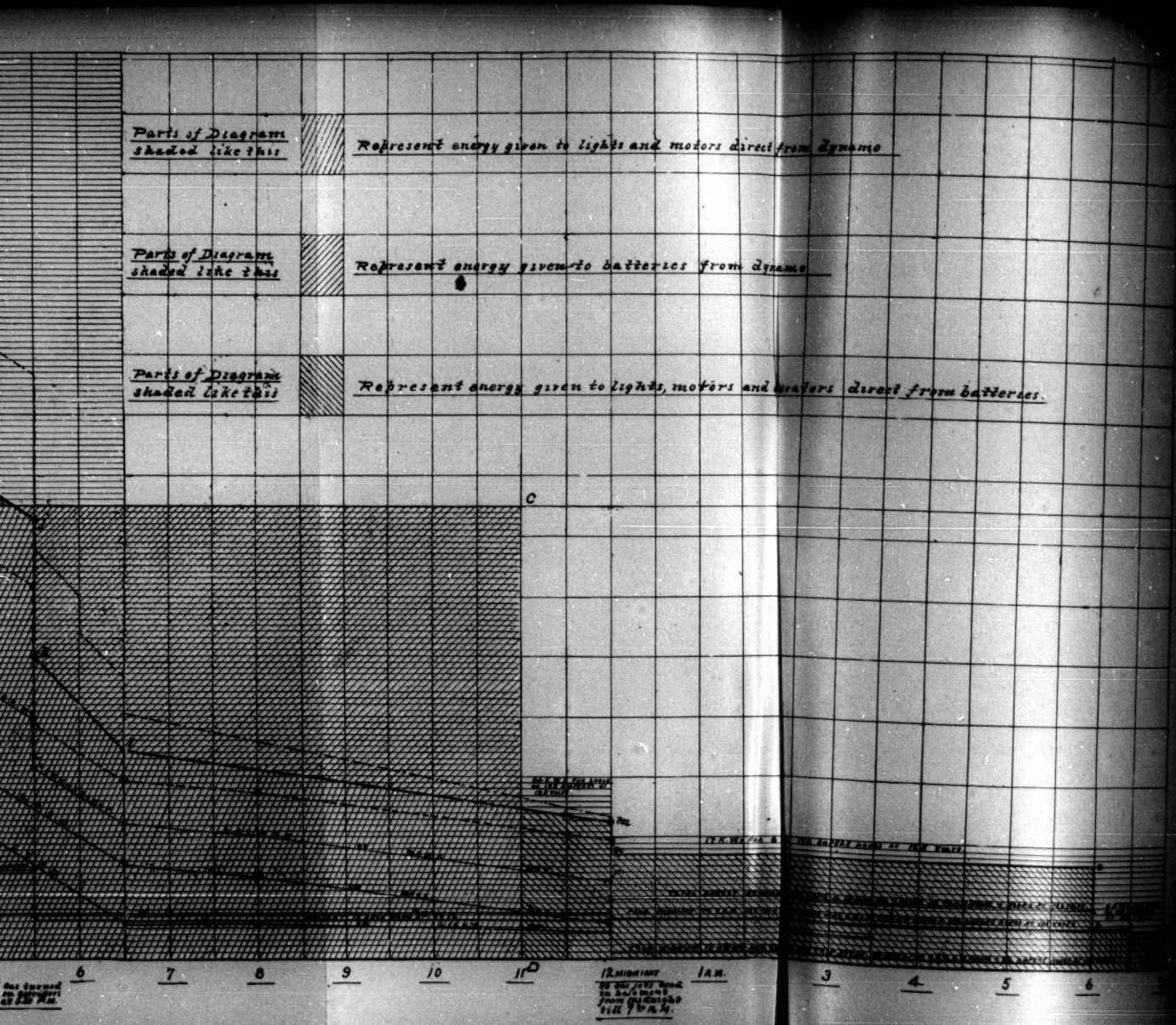


FIG. 3. Load Diagram of the Electric Plant of the C[illegible]go Board of Trade showing Pres



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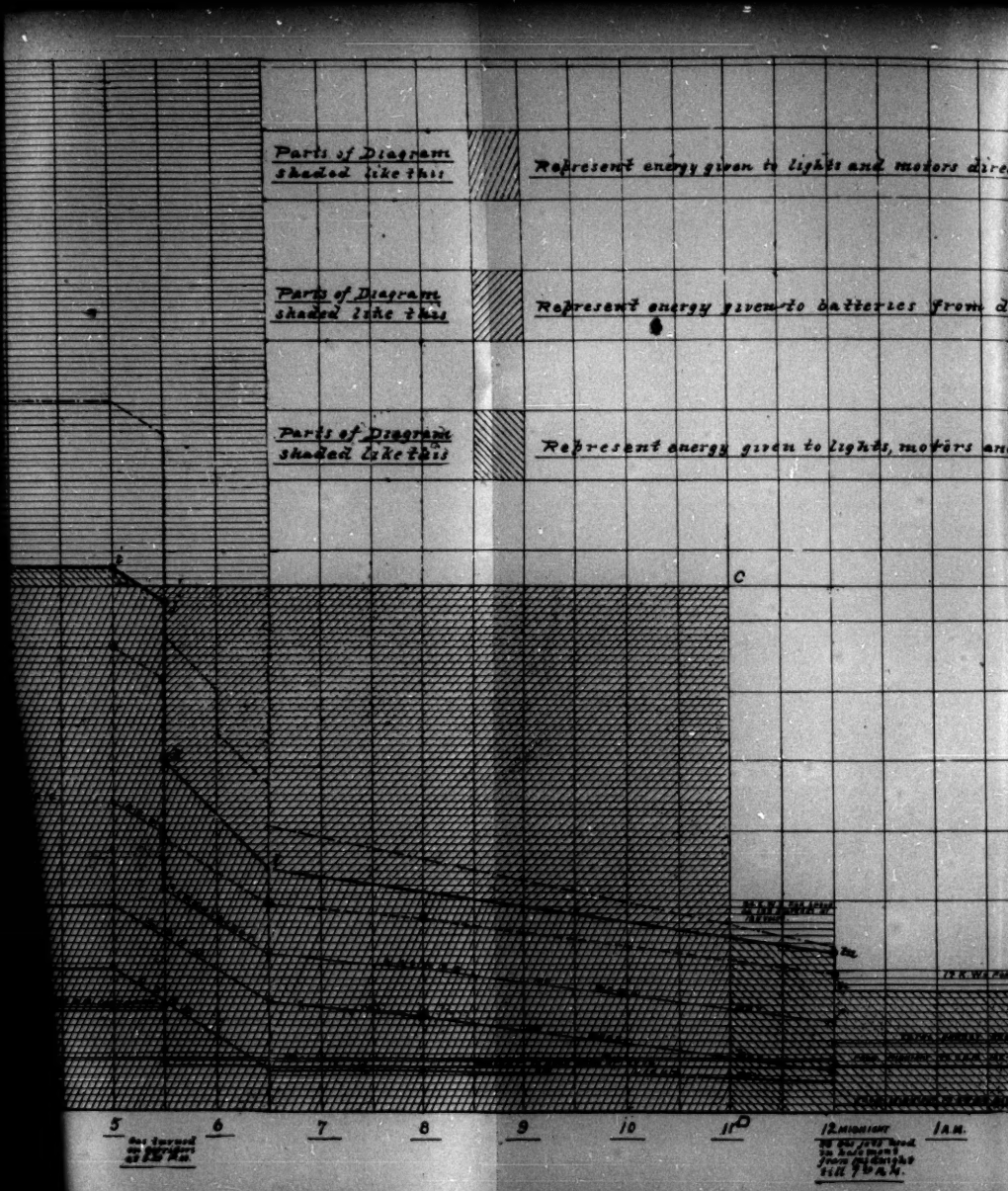

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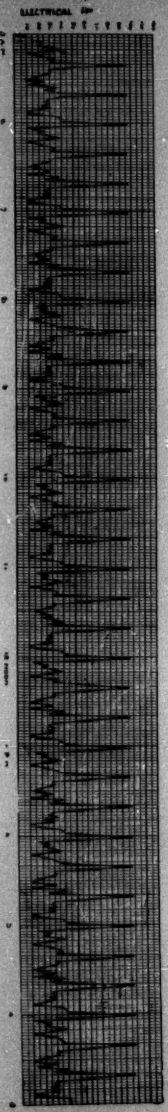

FIG. 2.

near Chicago. You will notice the similarity of the peaks, and that they occur at equal intervals of time. This is caused by the road having upon it a four per cent. grade, about one-quarter of a mile long, up which a car is propelled every 20 minutes, there being four cars in operation on the line, and so spaced that the cars reach this grade 20 minutes apart. The result is, that it was necessary to install a very much larger engine and generator in this station, in order to take the maximum load of the line when the car reaches this grade, necessitating the operation of a 250 H. P. engine the entire 18 hours that the road is in operation, merely to be able to haul one car up this grade, and to operate the other three at the same time. This was the first case that occured in my experience wherein I thought it advisable to recommend the adoption of a battery auxiliary. After making an accurate test of the plant, I found that the total average energy required from the power station to operate the road was about 50 electrical H. P.; consequently, if an engine and generator of 65 H. P. were installed and working in conjunction with a battery auxiliary, the road could be operated with this size plant, and the large engine shut down. I am unable to give you the results of this installation, as it is not yet running, but hope to at some future time. You will readily see that an investment for a 65 H. P. engine and generator and a battery auxiliary, to do this work, is much less than is at present carried to do the same work.

The most important application of batteries to lighting work, which I have had to do with, is the plant now being installed in the Chicago Board of Trade. In this plant the operating expenses average now about $25,000 per year, using simple engines at 75 lbs. of steam, hydraulic elevators with compound pumps working steam full stroke, and old style belted electric plant with shafting. By increasing the steam pressure to 125 lbs., installing new boilers, new compound engines, and with direct connected generators, electric elevators and a battery auxiliary, we expect to reduce the operating expenses to $15,000 a year. The present system of operation necessitates the use of three shifts of men, working eight hours each, making the labor pay-roll rather high. With the new system, using the battery auxiliary, there will be but two shifts of men, working eight hours each; a third man working but eight hours, thus reducing the cost of labor in the plant very materially, as the battery takes care of the entire load for a period of eight hours. At present it is necessary to signal to the engineer to start up the engines and dynamos when the janitors require light at night, while sweeping the rooms, and to use the hydraulic elevator. With the new system, the battery will handle the elevator and lights in the building automatically at night.

Referring to Fig. 3, which represents the load diagram of the plant of the Chicago Board of Trade as it now is, and as it will

be when the revised plant is in operation; the lower lines of the diagram, representing the various lighting loads, and the large line *A*, *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *j*, *k*, *l*, *m*, *n*, *o*, *p*, *q*, representing the load of the plant for 24 hours under the new conditions. The parallelogram *A*, *B*, *C*, *D* represents the total electrical energy of the 75 K. W. generator, operating from 7 o'clock A. M. until 11 o'clock P. M., over a period of 16 hours, involving two shifts of labor at eight hours each. That portion of the parallelogram, having shade lines inclining to the right at an angle of 45 degrees, represents the energy which will be delivered from the generator to the batteries. That portion of the diagram having shade lines inclining to the right, at an angle of 120 degrees with the base line, represents the energy which will be delivered to the line direct from the generator without the aid of the batteries, while that portion represented by the shade lines inclining to the left, at an angle of 45 degrees, represents the energy given to the line from the battery alone. It will be noticed that between the hours of 9 A. M. and 2 P. M. the batteries act in conjunction with the generator, as the demand is in excess of the capacity of the generator, while from 11 o'clock P. M. until 7 A. M. the entire load of the plant is carried by the batteries without the aid of the generators, thus leaving all of the plant, except the batteries, idle for this period of the twenty-four hours, and necessitating but one attendant during this time, who fires the boilers in the winter for steam heating, and also acts as watchman. With this arrangement, the 75 kilowatt, unit operates for a period of sixteen hours at its maximum economical load, and is then shut down and stands idle until the next operating period. From this plant will be operated 1,000 16 C. P. incandescent lamps, four 10 H. P. electric motors, four 30 H. P. electric elevators, and it is expected that one 75 K. W. generator will handle this load economically when the plant is completed, it being understood that the maximum capacity of these machines is seldom required at any one time. With this arrangement, lights or power can be turned on any part of the building at any time during the entire 24 hours of the day without necessitating any attention from the engineer in charge, thus gaining not only economy, but a great feeling of relief on the part of the operators, which they do not now have, or for that matter do not have in any plant operating on a variable load without the use of some kind of a reservoir, in the shape of a large engine, running underloaded, or a battery auxiliary.

Mr. Abbott has given us a very carefully prepared discussion upon the cost of the operation of the London lighting plants, when operating as they do now, and has shown what might be expected, if they were operated with battery auxiliary.

The records of European stations, so far as I am able to secure, show that the plants operating with battery auxiliary are delivering a K. W. hour to the consumer at a somewhat lower rate than

those operating without batteries, when the conditions are similar.

The chief difficulties which have prevented the introduction of batteries on a large scale in this country in the past have been as follows:

1. The danger of suits for infringement wich were liable to follow in case a purchaser attempted to use batteries.

2. The desire on the part of the manufacturer to furnish a battery for as low a cost as possible, and in many cases installing them of too small size to do the work required, the result being rapid deterioration and subsequent disastrous results to the battery business.

3. The lack of knowledge on the part of the operators or attendants in charge of the batteries.

A battery plant properly built, with sufficient lead to do the work required of it, and properly handled, will prove an economical investment where the conditions are favorable; but it should be borne in mind that a battery, like every other power-saving device, cannot effect a saving, unless the load is such as to warrant its use, which is especially the case on variable electric loads.

Those having charge of plants using batteries should bear in mind that batteries absorb and give out energy by virtue of a chemical action, and that anything which in any way prevents the proper harmonizing of the chemical elements entering into the batteries, begins to cause deterioration immediately. Consequently early attention must be given to defects, or serious results will follow. In other words, a battery plant is like any piece of mechanism or other device which requires some knowledge on the part of the operator to keep it in good condition, and as before stated, a large part of the battery failures in this country have been caused by the attendants not thoroughly understanding the device they were attempting to handle, and thus allowing destructive chemical action to continue until the batteries were practically destroyed, when attention at the right time would have prevented it.

The system which I have adopted for all plants installed under my direction is as follows:—*First*, I insist upon a recording ammeter being placed upon each plant, and daily charts from each plant mailed to my office. In this manner I am able to tell immediately whether or not the cells of any particular plant are being overcharged, overdischarged, or gradually discharged more than they are charged, until the surplus of the cells is exhausted, which is one of the chief sources of disaster in batteries. *Second*, each week the plant is examined by an expert, and the specific gravity of the electrolyte of each cell and the voltage of each cell examined and placed upon a report and handed in. From this we are able to tell whether or not the cell is short-circuited, or the electrolyte too heavy or too light for economical working, and

if defects are noted, the operator of the plant is notified immediately to remedy the defect, and if he is not capable of doing this, an expert is sent to do it. By this system of inspection it is hoped that a sufficient number of plant operators will become skilled enough to properly handle a battery installation, and after that time, I think, we will have fewer storage battery failures.

MR. MACFADDEN:—I would like to ask Mr. Arnold whether or not those tests on steam engines and on gas engines, were made on brake tests or indicated horse-power. I have found that in some gas engine plants with which I have had to do, that the gas used per indicated horse-power varied but little with different loads. It will be found that the gas used per indicated horse-power will run very nearly the same whether the engine is running under load or over load; also, that on some tests of a 200 H. P. engine, when on half load and under, we can get practically the same results for indicated horse-power, where consumption of gas is concerned, as we can for full loads. Also that the highest efficiency for this particular engine is not at the point of maximum possible load. I mean that the highest efficiency of that engine is not reached when the engine is doing its maximum work. I can take an engine that is designed to run 55 brake horse-power, load it up to 70 brake horse-power, and the engine will carry it. The highest efficiency is not obtained with the highest possible initial pressure that can be obtained. I think that this is somewhat different from the usually accepted views with regard to the gas engine, and I have the data which I will distribute to those who wish to investigate the matter. It would be especially interesting in this case, provided the tests were taken as indicated horse-power instead of brake horse-power. The amount of gas and fuel for indicated horse-power, I think, will be found to be somewhat different from brake horse-power. Mr. Perry gives the data of a test on horse-power development. I should imagine that this means in the cylinder, in the absence of anything stated to the contrary, the gas consumption being too low for brake horse-power.

MR. ARNOLD:—I would say that I have examined the engines you have referred to, and find them to be double cylinder engines which explode once at each cylinder, or twice at each complete revolution of the shaft, and it is undoubtedly true that such an engine can stand a heavy overload better than many types of gas engines.

PROF. CARHART:—I regret that I cannot give you any information on the commercial side, but I have been very much interested listening to the discussion here this evening. I have had a little experience, however, with storage batteries. Three years ago I had the pleasure of visiting, in company with several other gentlemen, the central stations of London, through the kindness of Professor Silvanus Thompson. We visited all, or nearly all, of them, and, as you know, the storage battery is an important

factor in all these stations. One thing that impressed me very much, in comparison with what I had been accustomed to see in connection with storage batteries in America, was the fact that they construct their storage batteries there for durability. The cells were of enormous size and capacity. They were extremely heavy, and intended for actual use. They were not made, apparently by the manufacturers, to make money out of, by selling cheap metal at a high price, but they were made for service and durability. In connection with that, it occurred to me that there must be quite an addition to the cost of the plant besides that of the battery installation, namely, provision for its storage. The building costs as much where the storage battery is used, as it does where it is not used, because of the very large area required for the placing of the batteries. There are a good many appliances, too, as you know, in connection with a storage battery plant in addition to the cells themselves. The arrangements for throwing cells in and out, according to the requirements of the plant, are very elaborate and costly. They are put up in an attractive and substantial manner. They are not placed in cellars, nor yet in attics, but in very substantial buildings. They are running their engines there at the point of highest efficiency, because the number of engines changes with the load. As the load comes on, additional engines are started up. And yet they find it economical to use the storage battery in connection with their plants.

Another item ought to go into Mr. Abbott's estimate, and that is, the cost of the acid required to set up the cells. The cost of acid amounts to considerable, for the acid ought to be of the purest quality. I have had a little experience with two types of battery. I think the Pollak battery is a thoroughly good one, but it certainly depreciates quite rapidly. In the one that I have, some of the cells have had to be taken out and repaired. The people in charge of these stations in London, which use storage batteries, watch them very carefully, and when anything is the matter with them, they put them in the hospital. Storage cells remind me of an invalid, requiring great care and watchfulness. They must be taken care of and watched, when they are not giving their highest efficiency. They require considerable labor, and this item ought to be added to the account. It requires the labor of one or two experts continually, to look after these cells. I think the last battery that I have tried, gave out toward the close of last year from the fact that it stood a long time without being used. I inquired of Mr. Pollak regarding this, and he assured me that it could be left standing. Mine, consisting of 36 cells, did stand without losing more than two volts in three months. The voltage scarcely dropped at all. I measured carefully to assure myself that it kept its voltage during that period. But there was sulphating under the active material, and when we came to use it, it would swell in spots. Mr.

Pollak insisted upon it that some foreign material must have gotten into the cells which caused them to give out. But I think it came from the fact that the cells were not kept in constant use. I found that it don't do to let them stand. It is like the human body in this respect, the cell needs exercise to keep it in good condition.

I have come across one or two points of scientific interest. It is certain that the internal resistance of a storage battery changes considerably with the length of time that it is discharged. As it is discharged, we have a sulphate formed, which has a higher resistance than the active material. This internal resistance will change in the course of charging for half-an-hour. Then there is another point. You all know that the internal resistance of any primary battery decreases as the current increases. We have been able to get very nice smooth curves. With a storage cell the change is small and is quite difficult to measure, but measurement shows that the internal resistance is lower when the current which we are taking from the battery is larger.

MR. ARNOLD:—When you start charging a battery, you can force current into it for a while with a lower voltage than you can when the battery becomes partially charged. Is not part of this attributable to the lower internal resistance of the battery when not fully charged? As the cells become charged, it is necessary to increase the voltage of the charging current in order to keep the charging current constant. This must be due to the increased internal resistance of the battery. It is well known that the resistance of a mixture of sulphuric acid and water is least, having a specific gravity of about 1.123 at ordinary temperatures, and, as the specific gravity varies either way from this, the resistance increases.

PROF. CARHART:—The internal resistance falls as you charge, because the sulphate is reduced, and for that reason it ought to take less voltage to force the current through. The battery does not have as high efficiency when it is discharged with a large current as when it is discharged with a smaller current, but the smaller internal resistance is a slight offset.

MR. DOMMERQUE:—I remember that the company which manufactured the accumulators for Hanover, Germany, has made a contract with the city to keep them in perfect running order at four per cent. of the first cost for ten years, and that this company makes money at that, which I conclude from the fact that when I was there in 1887, they ran their factory by a small locomobile, while to-day they have immense factories at Hagen, Berlin and Vienna. In most stations the accumulators have a space about one-half to one metre square for each cell. On the Continent I found that they do not give accumulators a very good place, but put them in basements, or somewhere where the ground does not cost so much. I think this is cheaper than to provide space for engines or dynamos instead, because the latter must have a good foundation.

PROF. W. M. STINE:—It seems singularly appropriate to enter a plea for the proper consideration of the storage battery itself in connection with its engineering applicability for lighting and power uses. It is 35 years since Gaston Planté (1860) made the first experiments from which the storage batteries of the present have been developed. The field has been a prolific one for investigation and invention. The storage battery is thus older than dynamo-electric machinery by about seven years. Sufficient time has certainly elapsed for the practical development of this class of apparatus. Yet after 35 years we are still telling each other how excellent a thing the storage battery would prove, were it only more generally used, and still in the dark for reliable data on which to base our conclusions.

There is good reason for the lack of data for the life and usefulness of storage batteries. Through all the years they have been with us, they have existed in tentative form, and their history is a failure of one form, leading to fresh experiments on others. That they have recently been the subject of large speculation by some of our leading financiers is by no means a convincing argument in their favor. This is neither the first nor the greatest financial combination of its kind, and should it not prove successful, it is only adding one more to a long list of disastrous failures.

The engineering view of our subject has been frequently and pretty exhaustively presented, but too often by those who have had no practical experience with batteries, and whose estimates of first cost, maintenance and depreciation are far below the actual figures.

A commercially practical storage battery would be one of the greatest boons to electrical engineers. This is undeniable. It does not require any especial foresight to realize the great advantages accruing from their use. The problem of when and how far to employ them, is not more difficult of solution than the most advantageous amounts and distribution of copper in distributing circuits. It requires that a sufficient number of load curves be taken to get a reliable average curve. It then remains to determine the size of generating plant to handle the average load, and the addition to this to handle the peaks in the load, allowing sufficient reserve to handle the maximum peak likely to occur. The equivalent in batteries of this reserve portion of the plant can then be calculated. The total operating expense in each case would present no especial difficulty, were data at hand, which would reliably state the depreciation, maintenance and labor involved by the use of storage batteries. Additional elements would be the enhanced efficiency of the generating plant when run with a nearly constant load of the service and battery combined, and the power factor of the batteries, or their efficiency from the generator to the consumer. With such data as outlined, the question of the commercial applicability of the

storage battery would be a very simple one. All that would be necessary would be to balance accounts between the two classes of reserve plants. On the one side would be the first cost of generators, engines, boilers and accessories, labor, maintenance, operating expenses and depreciation. On the other, the first cost of the reserve equivalent in batteries, their maintenance, depreciation, operating expenses, labor, and the large number of accessories. Here conscientious calculation would leave but little room for discussion, except on methods and details of installation. If the problem has been fairly stated, then why does the present hesitation to install batteries exist? There is no doubt that storage batteries would prove desirable adjuncts to many power and lighting stations, and would be generally introduced, could any reliance be placed upon such low depreciation as 7½ per cent., as has been recently stated.

But American engineers are justly conservative on this latter point. In too many cases the depreciation has reached 100 per cent., or the batteries have been abandoned in a short time.

It is undeniable that a strong sentiment exists in this country against the storage battery. Most of the data obtainable is against it. Under such circumstances it would be wise to make haste slowly, and let the burden of the introduction of batteries rest on the company manufacturing them.

The argument that the engineering world wants, is not engineering calculations showing a paper economy, but it wants to be granted the demonstration of plates that have stood at least from 1,500 to 2,000 daily reversals on continuous service. A battery of which at least 90 per cent. of its plates could make such a showing would be not a mere curiosity, but a most convincing argument.

The general trend of practice is to employ a greater weight of lead per ampere-hour capacity. Those who have had much experience with storage batteries know that plates fail from at least three causes: (*a*) the loss of active and irreversible material falling to the bottom of the cell; (*b*) rupture of plates due to mechanical strains; (*c*) disintegration, or crumbling of the supporting structure of plates.

Heavier plates, then, will remedy the second and third faults to a limited extent, but be without influence on the first. The heavier plates suffer the same actual loss in pound weight of active material as lighter ones, but can support the loss for a greater length of time. But the proportionate life of a heavy plate, owing to physical disintegration, may in reality be less than the lighter one. The interest on the first cost of the extra lead which is used to ward off the day of final destruction, is a direct loss, unless the proportionate life of the heavy plate greatly exceeds that of the lighter one. The use of more lead in plates, by no means diminishes the wear on batteries.

It has been so often proven that the use of reliable storage

batteries is excellent engineering practice, that the arguments have become mere platitudes. But where shall we obtain the reliable battery? Certainly it is yet to be proven that it is made in America. Can we point to any make of battery that has stood up under at last five years of ordinary commercial service? The records of the Patent Office show that the storage battery has received its full share of attention from inventors, and yet we hear the common report from the different styles of plates that they have gone to pieces under short service. Litigation is claimed to be responsible for the non-use of storage batteries in this country. Yet we all know better than this. If a perfectly reliable battery had existed, it would have come to the surface in spite of all lawsuits. The very fact that manufacturers are constantly changing the form of plates, etc., is sufficient argument to show that plates will not stand up under service. Great stress is laid on the extensive use of the storage battery in England, Germany and Switzerland. But here the plants are too modern to prove their ultimate economy. One of the oldest and best known of English plates is rumored to be proving a failure, for the very reason that this plate has been in use long enough to demonstrate that it does not possess sufficient life.

European practice offers a counter argument. The fact that batteries are used there so extensively, shows that they must prove at least a partial success. Let American engineers, then, profit by European experience. Let us go to them for our information. But how shall this be obtained? The suggestion is offered that our technical papers procure from European central stations using storage batteries reliable statements which shall, without fear or favor, state fully all facts in regard to their installation. Such data should note the style of battery in use, its ampere-hour weight, the purity and specific gravity of the electrolyte, the methods pursued in operating and caring for batteries, first cost of batteries and accessories, their actual power factor, the outlay for repairs and renewals, the length of time the battery has been in actual service, and the life of plates so far as used.

Another question remains to be decided. Can batteries be profitably sold outright? In very many cases the manufacturer has maintained a fostering care over plates installed, and the life shown has in a measure been due to frequent patching up of plates.

Among points not sufficiently emphasized by many writers, is the great outlay for the numerous expensive accessories demanded by a first-class installation; the constant attention and treating which they demand, and the disagreeable nature of repairs due to handling sulphuric acid.

A notable article appears in the *Elektrotechnische Zeitschrift* for October 17, 1895. It fully states just such data as we desire, for an installation of 120 cells of Tudor battery made in Hagen, Westphalia. The cells were 52 ampere-hours capacity; normal

discharge rate of 10 amperes, and charging current of eight amperes. The battery was installed in 1890, and has been in constant use. With the exception of renewal of electrolyte in one cell, no repairs or renewals were necessary. The installation was for the Head Bureau of Telegraphs in Berlin, and used on its service wires. The discharging current never exceeded 0.25 amperes. The cells were charged each 10th—11th day. On analysis of the record, owing to the small discharge current, we can draw no conclusions as to what would have been the life of the plates under conditions of normal discharge, say 5 to 10 amperes. These batteries in all have been reversed not to exceed 200 times, this being equivalent to not more than one year's active service, such as would have been required of them in lighting and power plants. An increase in capacity is noted, a condition which is to be expected under such service.

It is to be hoped that this timely article will be followed by many others equally reliable.

Mr. Arnold:—In referring to the maintenance, it seems to me that the best evidence that could be relied upon is the guarantees which are made by the companies that are backing these battery installations with their money. They are not going to guarantee something which they do not believe they can depend upon, and I do not see any reason for doubting their ability to do this, when they are willing to make contracts which make them liable if they are not able to fulfil their promises. I believe batteries can be maintained at a profit for seven and one-half per cent. of their first cost per annum when working within their limits.

Up to the present I have not been in favor of batteries being put upon street cars, but figures which have recently been shown me from the records of a road operating 25 cars in Paris, in which the maintenance of batteries is given at $\frac{6.8}{100}$ of a cent. per car mile, covering a period of over two years of operation, causes me to look upon this question more favorably, and if on investigation this record proves to be correct, many of us may have to change our minds regarding storage battery cars. One thing is certain, that the first cost of a road is less with storage battery equipment than it is with trolley equipment, for the reason that the power station investment is less, and there is no expense for the overhead or feeder system. A set of cells in this city which have been used over two years now, none of which has been returned to the factory for repairs, are reported to me to be in as good condition as they were the day they were started. These are operated on a fluctuating load, but evidently have not been overworked. I attribute a large portion of the durability of this particular plant to the excellent quality of lead used in the construction of the cells. This, together with the use of chemically pure acid, and the careful attention which has been given by the operator who is an expert on battery work, has shown an excellent result, confirming more than ever my belief that the thing

we need most in this country at present is a class of trained men, capable of handling batteries properly, rather than radical improvements in the batteries themselves.

MR. FELDMAN:—In the *Electrician* (August 30) are given the latest results of using storage batteries by the Birmingham, England, Central Tramway Company to work the cars. The figures presented by the chairman of the company showed that while the mileage had remained stationary, the receipts had decreased six per cent., and the expenses increased 27 per cent., the total cost per car mile having grown from 14¼d. to nearly 18½d. The exact figures of the four different systems supplied by the company per car mile are as follows: Cable, 5.43d.; horse, 8.67d.; steam, 9.11d.; storage batteries, 18.43d.; while last year a profit of over £1,200 had been earned by the accumulator cars. This year the chairman reported a loss of £1,735.

MR. DOMMERQUE:—I had the good fortune to meet Mr. Tudor in 1887, and he himself told me that he had had accumulators in service for seven years, which he charged regularly. He says, that figuring on this basis, he could guarantee for 10 years, and that the repair bill would not amount to more than 10 per cent. of the first cost.

[Adjourned.]

BRADLEY ON PHASING TRANSFORMERS.

Discussion at Chicago, Sept. 25th, 1895.

[See pp. 494 and 624 *ante*.]

Mr. A. V. Abbott:—The subject this evening is of great interest, especially to those who are particularly interested in the electrical transmission of energy. When the continuous current first came into use we thought the problem was solved, but presently we found that the transmission was limited, owing to the fact that we could not build generators and motors to carry sufficiently high voltages to make the cost of conductors come within commercial limitations, resulting in the development of the alternating system. But presently it was found that the plain alternating system was practically confined, in its usefulness, to lighting work, as power distribution was not altogether a success. The polyphase system was then considered, and it was found that it was impracticable to give consumers all the power they needed on variable loads, and since then there has been a constant effort to find something that would combine the advantages of all the systems. If it shall ever be found practical to obtain a transformer which shall give us different phases from the same generator, there will be little more to be asked.

Mr. Fred. S. Hunting:—It seems to me that this is a most novel invention, and one which bids fair to be of great practical importance and to show excellent results. Every engineer knows that to-day there is very much more money invested in single-phase high period apparatus in central stations in this country than in any other incandescent lighting apparatus. Most, if not all of it, is very well adapted for incandescent lighting, and thus far serves its purpose, but it would be a great financial loss if these systems were to be displaced by a polyphase system capable of operating both lights and motors. Many stations could increase their earning capacity 50 per cent. or more, if they could furnish and operate motors from their present machines, and that without increasing probably anything but the fuel expense. In

view of the enormous investment in single-phase plants, it is almost imperative that we should have reliable and efficient motors for that system which will start with a powerful torque. Many of us have worked at this problem, and I am pleased to note the success Mr. Bradley has met with in this direction, and that it is not a mere paper and pencil or mathematical success. There is no simpler, more reliable (if well built) or efficient motor than the polyphase motor, and the combination of this motor with the existing single-phase systems is, indeed, a most fortunate invention. The invention of a successful and practical phase splitting or phasing, transformer at once puts the single-phase system on an even or more than even footing, because of its simplicity, with the polyphase system for the distribution of both light and power. With a phasing transformer it is at once possible to obtain from the single-phase systems any number of phase currents that may be required by any motor. The constancy of the phase difference in the currents delivered by this transformer is, of course, vital to its practical utility, and the motor, no doubt, helps to steady the phases. It is interesting to note how perfectly steady this phase difference is in the transformer described. Any one who has stopped to study the induction motor will realize, and if he has built them, will realize still more, how difficult it is, especially in the smaller sizes, to keep the magnetizing or idle current in them down. With a large number of small motors, which would be what many plants would have, the idle current would become a serious question. In this transformer it is possible to have the condenser serve the double purpose of assisting in the phase changing, and in largely eliminating the idle currents. It is, it seems to me, very fortunate that with this construction you have a leading current at full load, and a lagging current at no load, because it brings the point of either lag or load more nearly the average working load point of the motor. I have no doubt if desirable, that the full load current could, by proper proportioning of the apparatus, be caused to lead more yet. I regret that Mr. Bradley has not given us some actual figures in the way of an actual test, but this, no doubt, we may look for later. Condensers are destined, I believe, to come into very general use in connection with induction motors in order to take care of idle currents. A cheap, compact and reliable condenser will be the first requisite; and it certainly seems, from Mr. Bradley's paper, that he has succeeded in building one that should be very reliable and is very compact. I hope that at some time in the near future we may learn more about this condenser. The compactness will depend upon the E. M. F. that it can be worked on and be reliable, being more compact as the voltage used becomes higher. It is certainly an advantage both as regards the condenser and the motor, to be able to locate the condenser on the primary and use a comparatively low voltage on the motor. I am glad that we have an opportunity to see the motor in actual

service, and that Mr. Bradley has seen fit to so demonstrate what the apparatus will do, instead of resorting to numberless mathematical equations. If Mr. Bradley will next give us a period changing transformer without moving parts, I am sure his plans for long distance or short distance railroad work for that matter would take on a genuine Western boom.

MR. ABBOTT:—To what extent would the condenser be affected by lightning? While condensers can be made solid pieces of apparatus, they become exceedingly expensive ones when made to stand very high voltage. Condensers will be frequently subjected to atmospheric changes from which lightning arresters would not protect them. It is practically impossible to use a liquid condenser on the primary.

MR. W. S. HULSE:—Oil condensers have been tried, but up to the present time their results have not been altogether satisfactory. The effect of lightning, should it enter the transformer, would probably be to burn out the condenser or coils, and, perhaps both; placing it, in this respect, on a par with any transformer. However, for lack of experience which can only be obtained from the every day operation of the system, I can not tell what precautions would be taken to modify this danger should the ordinary means fail.

PROF. STINE:—Of course, the whole question of any form of distribution of this kind comes to the total cost. Here is an apparatus which is somewhat more complicated than we are accustomed to employ. The question arises as to what the cost of the same will be, and what the cost of its idle load will be. During the time that the combined system is in service, would it take more watts than the ordinary system? Is its cost likely to be greater than the cost of other systems which require perhaps a larger amount of copper in the line, owing to the necessity of more wires or other things of that sort, and will it be likely to be a question of serious moment? Are there any facts bearing upon this point? The magnetizing current or the current which the transformer is taking from the line when the motor is cut off, is very small, and no greater than that of an ordinary transformer of its capacity. This feature indicates a close similarity to any transformer system in respect to no load currents. As described in the paper, the condenser seems to keep from the line the idle currents found in the motor, and thereby gives the system a very high power factor. This feature reduces the cost of the line to a minimum, as compared with systems where the idle currents reach them—where they can only be provided for by larger amount of copper and, therefore, additional cost. A glance at the motor shows that it is very cheap to build. I suppose that reference is made to the first cost of transformer. There is no reason why the cost cannot be brought down to equal that of two small transformers whose added capacity will equal that of the motor or thereabout. The cost of the condenser will, of course,

be additional, as it is not included in the reference, and no figures can be given on it at present.

MR. BION J. ARNOLD:—I would like to see this system tried in electrical railway work. I have been hoping for something of the kind for sometime, and now we have reason to expect a trial of it some time in the near future. As yet, however, we have no results that we can depend upon. It is not yet in a state that would warrant any railway company taking hold of it. The principal objection to the operation of this system, as outlined here, for electric railway work, would be the bringing of the high voltage current in immediate contact with the car. The opposition which this would meet with from all sources, in carrying this voltage so near the passengers would be severe, but possibly this opposition may be eliminated, as the opposition to the practice of carrying 500 volts has been overcome. One other objection will be found, owing to the fact that an induction motor can be overloaded and stopped easier than a direct current motor, thus making it necessary to carry larger motors on the cars in order to meet the maximum demands of the car, and if we are compelled to carry a larger motor we must work it below its capacity, and probably at an inefficient rate. I should like to know more regarding the efficiency of the motor at various loads.

MR. HULSE:—It would be very difficult to state in figures the efficiency of such a system before the apparatus has been completed in its various sizes, but there is no reason why it should not equal that obtained from any well-designed three-phase motor under load, since it actually operates as such. In multiphase motors, when they are rated from one-half to three-fourths their actual breaking down capacity, it is quite possible to establish this point on its various characteristics, so that the motor is most efficient there, and the same is true for motors on this system. At light loads the efficiency should compare with that of any three-phase motor operating from a three-phase generator, at least there is no evidence to the contrary.

MR. ABBOTT:—The question of efficiency, however, would come in pretty seriously. There is no doubt but that the induction motor is as good, on the whole, in that direction as we could have. I certainly agree with Mr. Arnold's question as to the propriety of operating trolley lines at high voltages, and that brings up the question whether or not it would be practical to divide the railway lines into sections.

MR. HUNTING:—On any line it would be necessary to use a very much higher E. M. F. than you could carry on your trolley, even 1,000 volts, and we might even raise that, after a time, to 2,000 volts. The feeder lines could be carried on at any voltage up to 10,000 volts, varying with the length of the line.

PROF. STINE:—At this point the problem assumes a phase which seems to be giving the railway people some little uneasiness. The method of furnishing power, especially for freight hand-

ling, introduces the serious problem of dividing the sections evenly. The railway problem, if solved, I think will be solved on this line. Taking up Mr. Hunting's suggestion, these sections, or the second primaries, would occupy long stretches. The difficulty would arise from the distribution of the train loads. I recognize in this a means of using high primaries, and so you would have your whole equipment complete. You would have no idle transforming devices. It seems that in the change from steam to electricity, the capital invested in idle transformers for trains averaging from 2,000 to 5,000 horse-power would be saved. I want to express my delight at seeing this arrangement here this evening. I wish we could take up the suggestion of a period-splitter. I am not aware of any method known to physics by which you could split the period of a single phase. You can modify the system so that you can change the period, but given a single-phase system, there seems to be no way of splitting it. I would like to ask Mr. Hulse about this transformer. Most systems which have been adopted have found the condenser a source of weakness and expense to maintain, and have introduced a number of complications.

MR. HULSE:—The condenser occupies a space of a cube about four inches on a side, or about 64 cubic inches, including case and accessories. It was pointed out in the paper as well as indicated by the curves, that the impressed electro-motive force used in the tests was of sine form, and from them the operation of transformer and motor on complex wave forms could not be predetermined. Since the writing of the paper the transformer and motor have been operated very successfully on the Wood alternator, which, being ironclad, possesses a peaked complex wave form. It has been running before you under load on a current supplied by a small Westinghouse machine, and I think its successful operation is well established. In no case has it been found necessary to alter the adjustment in the transformer.

MR. ARNOLD:—We have all been very much instructed and interested with the paper read here to-night. I am sure that I, for one, appreciate it, and move that a vote of thanks be extended to Mr. Bradley, as well as Messrs. Hulse and Hunting, for the paper, and for the pains they have taken to display this apparatus to us.

MR. L. L. SUMMERS:—I wish to second Mr. Arnold's motion, and would like to add that I have the highest admiration for the forms of motor he has shown us this evening.

MR. ABBOTT:—Let us hope that these experiments will be continued in the near future, and that we shall shortly have the pleasure and benefit of some further information along the same lines.

MR. HULSE:—I would like to thank Prof. Stine for rendering us his valuable assistance in setting up this little apparatus.

[Adjourned.]

LOCAL ANNEALING OF HARD-FACED ARMOR PLATES.

A meeting of the Western members was held in room 1737 Monadnock Block. Mr. C. C. Haskins was elected chairman for the evening. The paper by Mr. Lemp (see page 637) was read by Mr. George Cutter, in the absence of the author. Following the discussion, a paper on "The Rating and Behavior of Fuse Wires," (see page 654), was read by the author, Professor W. M. Stine.

Discussion at Chicago, October 26, 1895.

Mr. Arthur V. Abbott:—The subject of annealing armor plates, as presented this evening, I think opens quite a broad field in the special use of local heating by means of electric current. While the particular application here instanced, that of annealing armor plates, is probably one which would be more useful to the various governments of the world than to commercial enterprises, yet the application of this method of local annealing will be advantageous to all who deal with surfaces of iron and steel. For example, I have known of instances where unequal chilling of the ring forming the tires for locomotive wheels has resulted in loss of the forging, owing to there being no means of locally changing the hardness of the metal at the chilled points. If by some means, such as the method set forth in the paper this evening, we can effect local annealing without injuring the rest of the material, or changing its characteristics, it appears that the process could obtain an extensive application in the various branches of steel manufacture. Such a process would seem to be particularly advantageous in the manufacturing of steel rolls and other forms of steel castings.

Mr. Samuel Rodman, Jr.:—The paper which has just been read is particularly interesting and instructive. I do not know that I have much to add to what Mr. Abbott has said on the subject except in regard to one point, and that is in using this annealing process, we must confine ourselves to those materials

which have a fugitive temper. In the case of certain materials, such as chilled iron, the hardness is permanent, a characteristic brought about by the sudden cooling of the molten metal as it comes in contact with the chill molds in which it is cast. If the rolls be made of steel, I should think, as Mr. Abbott suggests, that the electrical annealing process would be very valuable in rendering uniform the hardness in various portions, but the metal known as "gun metal" (which, chilled, is used in Germany, and probably will be in this country, for sea-coast fortifications, weight not entering as much of a factor as it does in the armor of war-vessels), would not be susceptible to this annealing process.

One other feature in this paper to-night has attracted my attention, viz., the applicability of this process to the construction of burglar-proof safes, a business with which I am somewhat familiar, though more in the sense of destruction than of construction.

Ordinary or laminated safes as usually constructed are made of plates of steel bolted together. The structure is first set up when the plates are soft and the bolt holes made, always a little larger than the bolts which are to be put into them. This is necessary in order to allow for certain warping and twisting in the plates which invariably takes place in the tempering process. The structure is then taken apart and the plates tempered, and finally put together making the finished article. The result, owing to the necessarily uneven warping and twisting, is a very ricketty and unreliable affair, and I should think the process described in the paper to-night would be very valuable in connection with such structures, if it can be applied to approximately thin plates, say one-half inch or one inch, of hardened steel.

MR. ABBOTT:—I referred to the use of rolls made of steel castings. The use of the chilled iron roll is disappearing.

Iron rolls are valuable as having a surface hardness which is not obtained perhaps in any other metal. On the other hand, they lack the wearing quality and the strength of those made from steel. The makers of steel castings have experienced great difficulty in obtaining the necessary uniformity. It is very difficult to pour a large steel casting which can be machined all over without discovering hard or soft spots. When the surface of the metal is unequally hard, uniformity in machine work cannot be attained, as the tool will cut more deeply in the soft spots and less in the hard ones. Thus, not unfrequently, castings are lost, from the impracticability to machine them with sufficient accuracy. It appears to me that such cases could be treated by local annealing.

THE RATING AND BEHAVIOR OF FUSE WIRES.

[See page 654.]

Discussion at Chicago, October 26, 1895.

Mr. A. V. Abbott:—The paper that we have just listened to appears to me one of the most valuable contributions to the literature of "fuse wire," as it contains the first (so far as I am aware) attempt to make an accurate, comprehensive and systematic study of the behavior of fuse wires, with apparatus and investigators who were fully competent to the task undertaken, and I for one am exceedingly indebted to Professor Stine for the information thus placed before us. There is one point, however, upon which I am not quite clear. In the circuit described by Professor Stine, and in the records of experiments, I do not discover whether any allowance has been made for the time constants of the relays used for determining the minute intervals of time under consideration. It has been shown that intervals of time as small as $\frac{1}{1000}$ of a second are involved, and it appears to me quite probable that the time constant of the induction coil used would be of sufficient magnitude to introduce considerable error when applied to the measurement of time intervals as short as .001 of a second.

It is possible that no better means could be devised, or those which would be more accurate, but in consideration of results so carefully worked up, it appears that the time constant of the relay or induction coil might introduce a serious error in the results, and my question is therefore only as to whether any allowance was made for the possible introduction of errors of this description.

Prof. Stine:—We have considered this point very carefully, but if you will note the connections, it is evident that the currents actuating the relays have at all times such small values that this error is negligible.

Mr. Abbott:—Does not the relay require a sensible time to impress its record upon the paper after the actual depression of the key exciting the relay or the closing of the relay circuit, and

is not this time a sensible fraction of the time which the relay is supposed to measure and record?

PROF. STINE:—There is undoubtedly a time lag in the action of the relays. Those were adjusted to as short range of armature movement as possible. The actual value of the time lag was of no consequence, providing the relays were adjusted to equal time lag. This adjustment was made as accurately as possible, thus rendering the relative time intervals extremely accurate. The time intervals were those showing the actual time of the throw of the switch and the blowing of the fuse.

MR. ABBOTT:—A still more important point is the bearing of the length of the fuse upon the disrupting current. I am not quite clear as to whether the experiments described indicate that after a certain length of fuse is reached, little or no variation in carrying capacity is observed. The disruption in the fuse is caused by raising the temperature of the metal composing it, to such a point as will melt it. The necessary heat is obtained from the energy developed in the fuse by the current. In any given time, the amount of heat contributed to the fuse is proportional to the square of the current and the resistance of the fuse wire. There are three causes of dissipation of heat:

First: Radiation which is due to the amount of radiating surface presented by the fuse wire.

Second: The heat lost by conduction to the terminals of the fuse, and there dissipated.

Third: The amount of heat absorbed in raising the temperature of the fuse wire and in melting it.

I have always had the idea that if the length of fuse was so great that the amount of heat lost by conduction to terminals was an insensible fraction of the heat delivered to the fuse by the current, no further increase of length would vary the carrying capacity of the fuse. In examining the curves illustrating the paper, it appeared that these curves indicated an approach to this condition, but from the fact that the lines did not become parallel to the axis, indicated that this principle was not carried out to such an extent as I had previously imagined to be the case.

Now, one other point: Are there any curves which went into that point particularly? That is to say, the ratio of the length of the fuse to its carrying capacity and the time?

PROF. STINE:—Such a curve was platted, and an approximate equation derived therefrom. Further investigations seemed desirable, and for this reason it has been withheld. We hope to give our results in an early communication.

MR. ABBOTT:—I have always felt that the emphasis of experimental evidence should be directed to convincing the people of the advisability of using long fuse blocks, thereby contributing to the reliability of such protecting devices. I would also like to ask why it was that no experiments were carried on for higher

currents than those which are shown. A greater proportion of the work seems to have dealt with currents of 40 amperes or under, while there are only one or two instances of the employment of 60 or 80 amperes. It would be interesting to know something of the value of the length of the fuse in its relation to currents of considerable magnitude, such as would be found upon our larger street railway circuits, and also the effect of alternating currents.

MR. LUDWIG GUTMANN:—I would like to know from Prof. Stine whether other experiments were made showing the proper rating under heat conduction. Would it not be better to make fuses of such lengths that they could be rated with conduction present, and thus raise their sensitiveness? If the same fuse may be rated higher when covered, would not this be better?

PROF. STONE:—I think that this point is clearly emphasized in the paper. We have advised just the opposite procedure. It is difficult to rate the value of condition, owing to variations of contact and the character of the contact surface. It seems better to use a fuse under such conditions that its blowing point shall be normally that of the fuse itself.

MR. ABBOTT:—Prof. Stine shows that in all cases there is an apparent interval of one or two seconds in all fuses, no matter what the current is before the fuse ruptures.

It appears from these experiments that no matter what the size of the fuse, or how large the current, there is an appreciable interval of time in which the smallest fuse might carry almost an infinite current.

PROF. STINE:—I think the maximum current employed was 110 amperes. The time lag was $\frac{348}{1000}$ of a second for everything above 40 amperes, and for three ampere fuses the time lag was $\frac{148}{1000}$ of a second.

MR. ABBOTT:—From the care exercised in the experiments and the reliability of the apparatus used, it appears that we can certainly trust the time readings to .001 of a second, or thereabouts.

The experiments show that there is a sensible interval of time amounting to from one to three seconds, during which the fuse does not fail, no matter how large the current is to which it is exposed. It would be interesting to know to what extent this increase of current for the first few intervals of time could be carried. It seems quite certain that if a small fuse were exposed to a large current of some thousands of amperes, an enormous amount of heat would be given to the fuse, and it is a pertinent question as to *what* becomes of this heat, and *why* it is that the fuse does not fail more promptly.

MR. LOUIS PRIVAT:—When an arc occurred on blowing the fuse, did you note whether the arc was sustained?

PROF. STINE:—We photographed an arc in a number of cases. Would that answer your question?

MR. PRIVAT:—Yes, partially. What I wished to get at was the destructive character of the arc. What is sufficient to cause a fire risk?

PROF. STINE:—That is a question we did not investigate, since we found the rupture of fuse to be quite uniform. One can scarcely speak of a sustained arc in the rupture of the fuse wire itself. The arc occurs only when the terminals of the fuse-block are too near together.

[Adjourned.]

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

ASSOCIATE MEMBERS ELECTED BY COUNCIL.

New York, Dec. 18th, 1895.

Name.	Address.	Endorsed by.
BANCROFT, CHAS. F.	Electrical Engineer, Lowell and Suburban Street Railway; residence, 60 Fort Hill Ave., Lowell, Mass.	C. P. Steinmetz. Wm. G. Ely, Jr. Ernst Berg.
HERDMAN, FRANK E.	Mechanical and Electrical Engineer, Crane Elevator Co., Winnitka, Ill.	A. V. Abbott. B. J. Arnold. W. M. Stine.
LAMB, RICHARD.	Chief Engineer, The Trenton Iron Co., No. 1 Broadway, residence, 73 West 69th St., New York City.	T. C. Martin. Jos. Wetzler. N. Tesla.
LE PONTOIS, LEON.	Electrical Engineer, The Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.	Chas. F. Scott. Henry Floy. Alex. J. Wurts.
LUDLAM, HARRY W.	With Western Electric Co.; residence, 480 Lexington Ave., New York. City.	Geo. A. Hamilton. M. E Canfield. H. F. Albright.
MCMEEN, SAMUEL G.	Assistant Engineer, Central Union Telephone Co., 1306 Ashland Block, Chicago.	A. V. Abbott. A. S. Hibbard. B. F. Thomas.
SCIDMORE, FRANK L.	With Western Electric Co.; residence, 480 Lexington Ave., New York City.	G A. Hamilton. M. E. Canfield. H. F. Albright.
STONE, JOSEPH P.	Electrical Engineer, General Electric Co.; residence, 213 Liberty St., Schenectady, N. Y.	C. P. Steinmetz. H. G Reist. Wm. G. Ely, Jr.
STORER, NORMAN W.	Electrical Engineer, Westinghouse Elec. and Mfg. Co., Pittsburg; residence, Wilkinsburg, Pa.	Chas. F. Scott. Alex. J. Wurts. Henry Floy.
THORDARSSON, CHESTER H.	Chicago Edison Co.; residence, 896 Davis St., Chicago, Ill.	Chas. A. Pratt. B. J. Arnold. W. M. Stine.

WYBRO, HARRISON C.	Electrical Engineer, Wybro & Lawrence, Los Angeles, Cal.	T. C. Martin. F. A. C. Perrine. Leo Daft.

Total, 11.

TRANSFERRED FROM ASSOCIATE TO FULL MEMBERSHIP.

Approved by Board of Examiners, Oct. 11th, 1895.

STEPHENS, GEORGE,	General Superintendent, Canadian General Electric Co., Peterboro, Ont.
WHITE-FRASER, GEORGE,	Electrical Engineer, Toronto, Ont.
DOW, ALEX	Engineer, Public Lighting Commission, Detroit, Mich.
NEILER, SAMUEL G.,	Assistant Electrical Engineer, Pierce and Richardson, Chicago, Ill.

Approved by Board of Examiners, Nov. 6th, 1895.

PEROT, L. KNOWLES	Vice-President and General Manager, Schuylkill Valley Illuminating Co., Phœnixville, Pa.
BLOOD, JOHN BALCH	Assistant Engineer, Railway Department, General Electric Co., Schenectady, N. Y.
SHEBLE, FRANKLIN	Electrical Engineer, Philadelphia, Pa.
FREEDMAN, WILLIAM H.	Tutor in Electrical Engineering, School of Mines, Columbia College, New York City.
RIKER, ANDREW L.	The Riker Electric Motor Co., Brooklyn, N. Y.
MCCROSSAN, JOHN A.	Manager and Electrician, Citizens' Telephone and Electric Co., Rat Portage, Ont.

Total, 10.

NOTICE.

Written discussions of the topic contained in this issue if acceptable, will be printed in the January number if received before January 15th.

The Secretary will esteem it a favor if his attention is called to any errors, in order that they may be corrected before printing the sheets for the annual volume.

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